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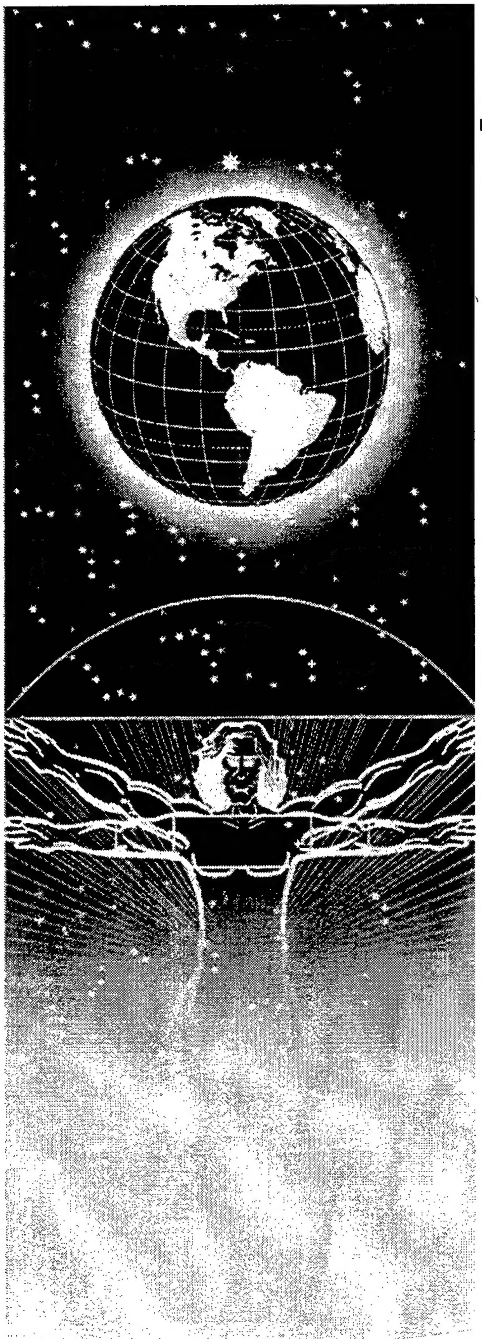

UNITED STATES AIR FORCE
ARMSTRONG LABORATORY

EVALUATION OF A PROPOSED B-2 SEAT CUSHION BY +Gz IMPACT

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Crew Systems Directorate
Biodynamics and
Biocommunications Division
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NOTICE

TECHNICAL REVIEW AND APPROVAL

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The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Thomas J Moore

THOMAS J. MOORE, Chief
Biodynamics and Biocommunications Division
Armstrong Laboratory

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13. ABSTRACT *(Maximum 200 words)*

Optimal seat comfort is required for aircrew operational effectiveness in all USAF aircraft. Extended missions in ejection seat aircraft must balance comfort with the cushion's influence on the risk of vertebral fracture during ejection. McDonnell Douglas and Northrop Grumman recently designed a proposed seat cushion for the ACES II ejection seat in the B-2 aircraft to improve sitting comfort. The Escape and Impact Protection Branch was requested by the San Antonio Air Logistics Center to evaluate potential spinal injury risk with the proposed cushion. A series of vertical impact tests were conducted with volunteer human subjects to compare the impact response of the proposed cushion to a "no cushion" impact condition, and to the existing B-2 ACES II seat cushion. All tests were conducted on the Armstrong Laboratory's Vertical Deceleration Tower using a +Gz peak impact of 10 G. Test results indicate that the human impact response with the proposed B-2 ACES II seat cushion is not significantly different from the response with no seat cushion or with the current B-2 ACES II seat cushion. This indicates that the current risk of spinal injury would not increase with the proposed cushion within the limits evaluated.

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PREFACE

The impact tests and data analysis described in this report were accomplished by the Escape and Impact Protection Branch, Biodynamics and Biocommunications Division, Crew Systems Directorate of the Armstrong Laboratory (AL/CFBE) at Wright-Patterson Air Force Base, Ohio. The tests were conducted at the request of the San Antonio Air Logistics Center (SA-ALC), and the B-2 Systems Program Office (SPO) at Wright-Patterson Air Force Base. All test articles were supplied through Mr. Dale Andrews at Tinker Air Force Base, Oklahoma. Test facilities and engineering support at AL/CFBE were provided by DynCorp Inc. under contract F33601-96-DJ001. A special thanks should be given to Mr. Doug Hopkins of the B-2 SPO for his perseverance in supporting the cushion evaluation.

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INTRODUCTION

The level of aircrew seat comfort is very important for acceptable operational effectiveness in many of today's high performance USAF aircraft (both fighters and tactical bombers). This is particularly true as some missions may have the aircrew in their seats for several hours; therefore, aircraft and ejection seat manufacturers are constantly evaluating new or improved seat cushion designs. However, even though long-term sitting comfort may be enhanced by a new or improved cushion, it must also be determined whether the cushion will influence the risk for vertebral fracture during ejection. Seat cushions can actually amplify the acceleration transmitted to the torso of the aircrew member if not designed properly. The cushion accomplishes this by delaying the onset of acceleration of the seat's occupant, or by absorbing the dynamic energy of the impact and then releasing it during recoil of the cushion material [2]. The advantages of improved sitting comfort afforded by a specific seat cushion in ejection seat equipped aircraft must be compared to the risk for spinal injury during ejection.

A recent effort was conducted by McDonnell Douglas and Northrop Grumman to improve the current seat cushion used in the ACES II ejection seat for the B-2 aircraft in order to provide a more comfortable cushion for long duration flights. A request was issued to the Escape and Impact Protection Branch by Mr. Dan Aldridge of the San Antonio Air Logistics Center to evaluate the proposed B-2 seat cushion in terms of increased spinal injury potential.

BACKGROUND

In 1985, a series of vertical impact tests (+Gz accelerations) was conducted by Hearon and Brinkley [3] to evaluate the spinal injury potential of several seat cushions (ACES II, F-111, and Temper and Confor foam rate-dependent foam cushions) compared to a

baseline no-cushion condition. The rate-dependent foam cushions were being evaluated due to their unique ability to provide a comfortable seating surface and to minimize the amplification of an impact acceleration pulse such as that experienced during the catapult phase of an ejection. The ACES II cushion in these tests had been constructed with a single, thin layer of Temper foam with energy absorption properties. Test results indicated that the rate-dependent foam cushions transmitted less energy than the tested operational cushions potentially decreasing the probability of spinal injury during ejection. The program aptly demonstrated the principle that human impact response is dependent upon the structural properties of the seat cushion. It should be noted that the program also demonstrated that fabric with dead space increased the dynamic response of the subjects.

Another series of tests was conducted by Brinkley, Perry, Orzech and Salerno [1] to evaluate a proposed seat cushion for the ejection seat in the F-4 aircraft. The proposed F-4 cushion was compared to the existing F-4 seat cushion and to the current ACES II seat cushion. The existing F-4 cushion was contoured, while the proposed F-4 cushion and the ACES II cushion were flat. The proposed F-4 cushion was composed of a rate-dependent foam, while the current F-4 cushion and the ACES II cushion were composed of multiple layers of different types and grades of foam. The ACES II cushion did have a thin layer of Temper foam as previously tested in 1985. Results were similar to the previous study indicating that the current F-4 cushion did not perform as well as the proposed F-4 rate-dependent foam cushion or the ACES II cushion in terms of impact protection.

The proposed B-2 cushion was approved by McDonnell Douglas and Northrop Grumman based on similarity to cushions previously tested (1985 study). However, there are some differences from the previous cushion tests that should be highlighted.

The proposed B-2 cushion has a sheepskin cover (like the current B-2 cushion) whose effects were not evaluated in previous cushion impact tests. The dead air space in the sheepskin cover may contribute to unforeseen impact responses. The new B-2 cushion composed of rate-dependent foams is approximately 1.5 inches thick at the buttocks compared to the cushion thickness in the previous rate-dependent foam tests which was 2.0 inches. The effects of this difference in cushion thickness may contribute to unforeseen impact responses. The new B-2 cushion has a contoured seat compared to the rate-dependent foam cushions from previous tests which were flat. The effects of a contoured rate-dependent foam cushion may contribute to unforeseen impact responses. Finally, the new B-2 cushion is composed of 2 layers of *different* rate-dependent foam material compared to the previous tests using rate-dependent foam cushions which were composed of a single layer. The effects of the multiple layers of different foams may contribute to unforeseen impact responses. Based on these differences, an experimental study was conducted to evaluate the impact acceleration performance of the proposed B-2 ejection seat cushion in comparison to the current B-2 ejection seat cushion.

METHODOLOGY

A series of vertical (+Gz) impact tests were conducted with volunteer human subjects to evaluate the impact response of the proposed B-2 ejection seat cushion. The new cushion was compared to the existing B-2 cushion. Tests were also conducted with a 'no cushion' condition for a baseline comparison. The experimental test matrix is shown in Table 1. The cell designations are not in alphabetical series because the tests were conducted in conjunction with an existing vertical impact program.

Table 1. Experimental Test Matrix

TEST CELL	ACCELERATION LEVEL	SEAT CUSHION
C	10 G	No Cushion
H	10 G	Current B-2
I	10 G	Proposed B-2

The current B-2 cushion is a flat cushion approximately 1.0 inch thick and composed of two layers of foam. The bottom layer is composed of 0.375 inch thick polyethylene foam (DMS 1954, Class 1, Grade 4101). The top layer is composed of 0.63 inch thick Confor foam (Type C-47 green) manufactured by Specialty Composites in Newark, Delaware. The cushion was approximately 19 inches wide by 24 inches deep. The proposed B-2 cushion is a contoured cushion approximately 1.5 inch thick at the buttock contact area, and approximately 2.5 inch thick at the back, sides, and thigh contact area. The bottom layer in each area is composed of 1.0 inch thick type Confor foam (Type C-47 green). The top layer in the contoured buttock area is composed of 0.5 inch thick Confor foam (Type C-45 green). The top layer in the raised cushion areas at the back, sides, and thigh was also composed of 0.5 inch thick Confor foam (Type C-45 green). These areas also included an additional layer of 1.0 inch thick Confor foam (Type C-45 green) between the top and bottom layers. These raised areas are what produced the contour effect of the cushion. The foam in both cushions was covered by a muslin cloth slipcover which in turn had a top cover of black sheepskin. Photos of the cushions are shown in Figures 1.

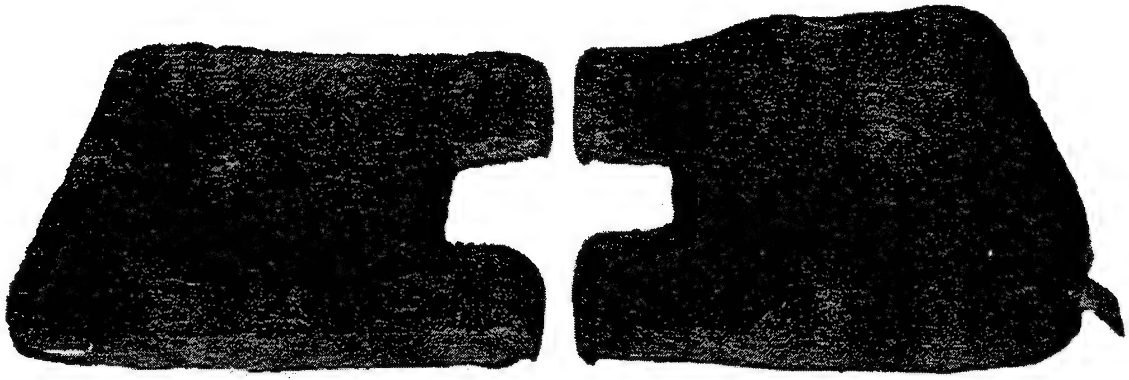

Figure 1. Current (left) and Proposed (right) Seat Cushion for B-2 ACES II Ejection Seat

All impact tests were conducted on the Armstrong Laboratory's Vertical Deceleration Tower (VDT). The VDT facility is composed of two vertical rails and a drop carriage. The carriage is allowed to enter a free-fall state (guided by the rails) from a predetermined drop height. A plunger mounted on the rear of the carriage is guided into a floor-mounted cylinder filled with water located between the vertical rails. A +Gz pulse (actually a deceleration pulse) is produced when water is displaced from the cylinder by the carriage-mounted plunger. The pulse shape is controlled by varying the drop height, which determines the peak G level, and by varying the shape of the plunger, which determines the rise time of the pulse. The VDT is shown in Figure 2.

To assure constant impact acceleration test conditions, the drop height, test carriage mass, and plunger type were the same for all experimental test conditions for the cushion evaluation. The tests were conducted at presumed sub-injury impact acceleration levels to minimize injury potential. The impact test pulses were a nominal 10 G peak half-sine waveform with an approximate rise time of 72 ms.

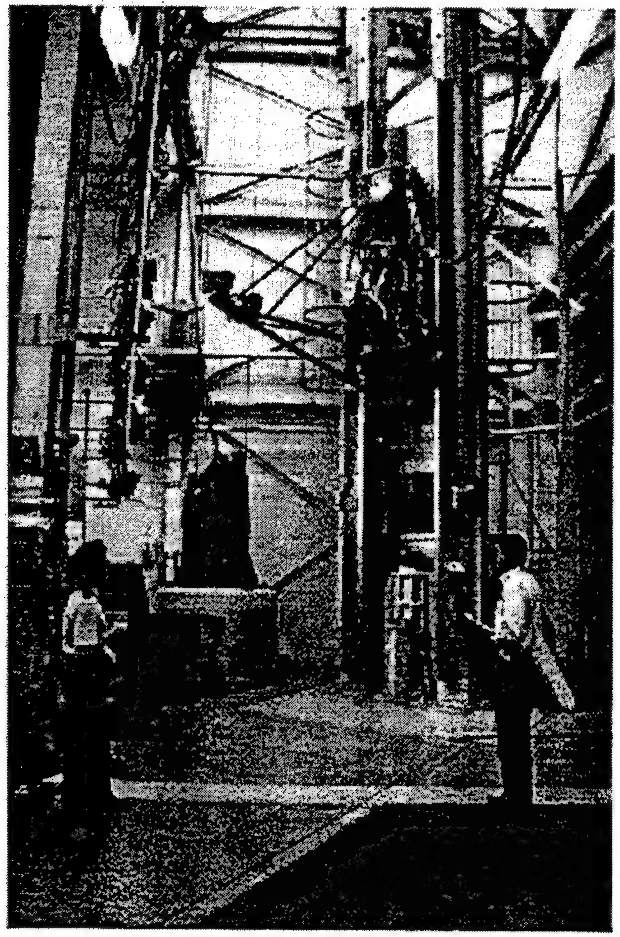

Figure 2. Armstrong Laboratory Vertical Deceleration Tower

A carriage-mounted seat is used to restrain a human or manikin test subject in an upright seated position. The carriage-mounted seat is generic in design and is composed of a flat seat back and seat pan. The seat back is perpendicular to the horizontal seat pan, and horizontal to the impact vector. The headrest was in-line with the seat back plane. A standard double shoulder strap and lap belt assembly was used as the restraint system in all tests. Prior to each test, the restraint system was pretensioned to 20 ± 5 pounds using load cells positioned at the shoulder strap termination point behind the head and at each lap belt anchor point. Each subject wore an HGU-55/P flight helmet and was positioned with head upright, helmet against the

headrest, and arms resting on the thighs. The carriage-mounted seat setup and the pretest position of the subject are shown in Figure 3.

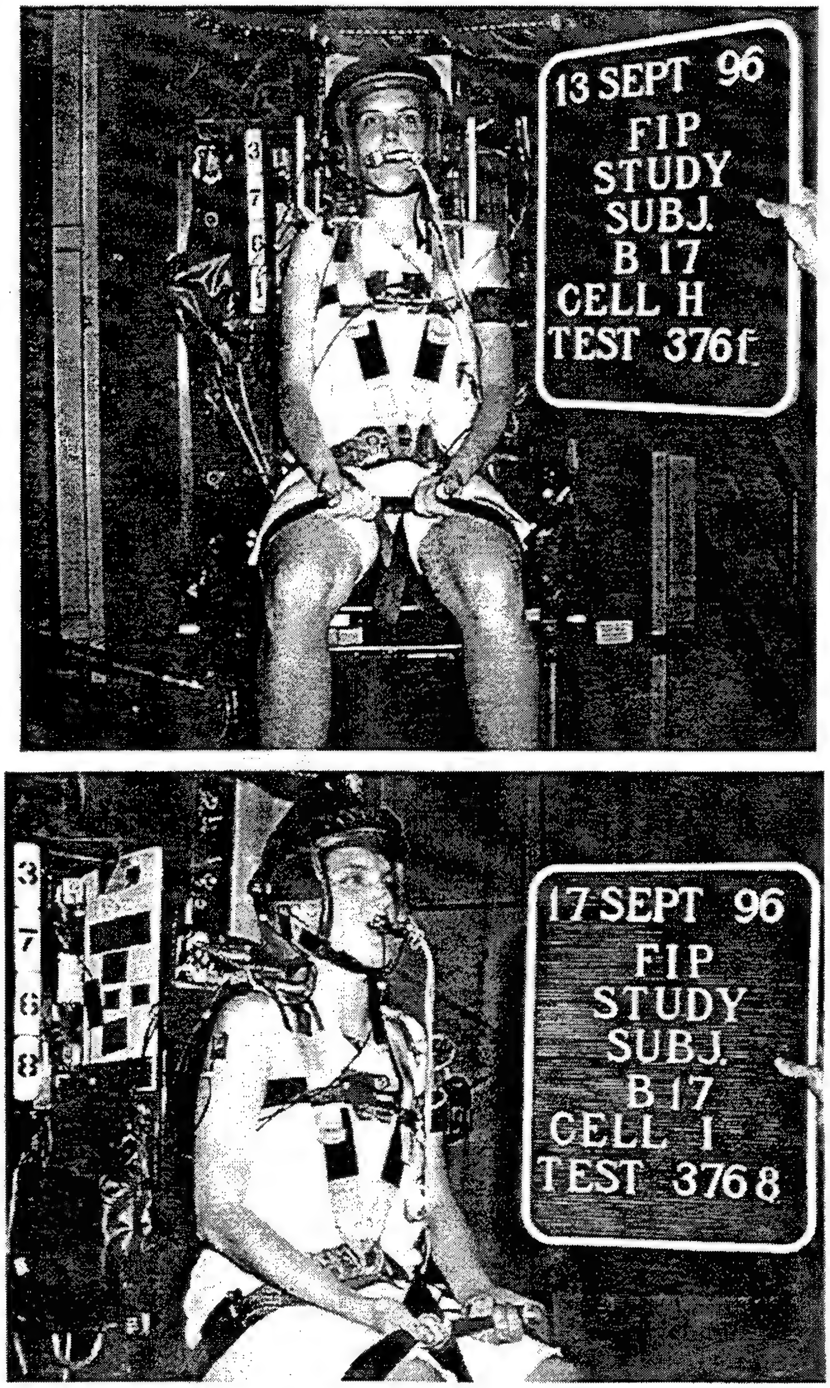

Figure 3. Front and Side Views of Test Setup Showing Seat and Initial Subject Position

All seat cushions were tested on a flat seat supported by a series of six force cells designed to measure seat pan loads in the three orthogonal axes (x, y, z). The flat seat pan was constructed of black delrin mounted to a metal plate used to interface the six load cells with the seat frame. Load cells were also used in the interface between the headrest and the seat frame.

As previously mentioned, the seat fixture and restraint system were instrumented with load cells to record the pertinent force data during each test. The subject and seat fixture were also instrumented with accelerometers to obtain relevant electronic data during each test. Measured parameters included acceleration of the VDT carriage and seat, subject's head and chest. Specifically, the subject was instrumented with an accelerometer pack composed of 3 orthogonal linear accelerometers and a single y-axis angular accelerometer using the right-hand rule coordinate system. The accelerometer pack at the head was located on a bite-bar held in the subject's mouth. The accelerometer pack at the chest was attached using a Velcro strap around the chest.

The 15 volunteer subjects (8 male, 7 female) were active duty officers and enlisted personnel at Wright-Patterson AFB. They were medically qualified for impact acceleration stress experiments through the completion of a medical screening more stringent than the USAF Flying Class II evaluation, and by meeting stature, weight, and sitting height criteria. The characteristics of the subject sample are comparable to the 1967 survey of the USAF flying population and are summarized in Table 2.

For +Gz impact, human tolerance is limited by vertebral compression fractures. Therefore, the key response parameters in this study were the z-axis seat load and resultant seat load which are generally indicative of vertebral column loading. The secondary parameters evaluated were the z-axis head and chest accelerations which also may indicate potentially harmful cushion-induced biodynamics. To limit the risk

Table 2. Summary of Human Subject Anthropometry

SUBJECT ID	SEX	AGE (yrs)	WEIGHT (lb)	STANDING HT. (in.)	SITTING HT. (in.)
B-11	M	35	229	72.2	37.5
B-17	F	26	126	67.0	34.8
C-12	M	35	191	68.1	36.6
G-11	M	28	171	69.5	37.8
J-7	M	28	164	67.8	35.6
J-10	M	23	200	69.1	36.4
J-11	F	21	159	65.7	34.5
K-9	F	27	137	65.9	34.1
L-11	F	30	138	64.8	33.7
M-30	M	35	183	70.0	37.2
R-21	M	36	220	71.3	38.1
S-11	M	32	219	71.2	37.0
S-20	F	27	122	67.4	33.9
V-3	F	26	116	63.9	33.8
W-8	F	30	127	66.8	35.0
MEAN		29.3	166.8	68.0	35.7
STD DEV		4.4	37.4	2.4	1.5
* USAF MEAN		30.0	173.6	69.8	36.7
STD DEV		6.3	21.4	2.4	1.3

of injury in a vertical acceleration environment, it is imperative that these response parameters be minimized.

RESULTS

All fifteen human subjects were exposed to vertical impacts in each of the three test conditions. Prior to statistical analysis of the test data, an evaluation was done on each set of data per cell per response parameter to search for outliers. The evaluation test

that was used was Grubb's Test [5]. Grubb's Test generates a range which the data can be expected to cover given a specific confidence level. The range is generated using the following equation:

$$G_R = \bar{x} + (s * T)$$

where G_R is the Grubb's Test data range, $\bar{x}$ is the data set mean, s is the data set standard deviation, and T is the Grubb's Test critical value which is dependent on the number of samples in the data set and on the confidence level. For this evaluation the T value was 2.407. A total of two outliers were found with one in the z-axis head acceleration data set for cell H, and one in the z-axis chest acceleration data set also for cell H. These data points were removed from the analysis for these data sets giving them only fourteen data points instead of fifteen.

Test results from the four selected response parameters (head z-axis acceleration, chest z-axis acceleration, seat z-axis force, and resultant seat force) are shown in Table 3. The mean and standard deviation are identified for each parameter in each of the three test

Table 3. Peak Acceleration and Load Test Data

RESPONSE PARAMETER	CELL C (NO CUSHION)	CELL H (CURRENT CUSHION)	CELL I (PROPOSED CUSHION)
Z-Axis Head Acceleration (G)	13.19 ± 1.29	13.61 ± 1.11	14.10 ± 1.30
Z-Axis Chest Acceleration (G)	14.93 ± 1.68	15.23 ± 1.27	15.00 ± 1.17
Z-Axis Seat Load (lb)	2318.30 ± 439.64	2318.05 ± 471.08	2341.89 ± 494.14
Resultant Seat Load (lb)	2320.51 ± 439.77	2322.08 ± 473.21	2344.95 ± 495.38

conditions (no cushion, current cushion, proposed cushion). The z-axis response of the primary parameters was chosen for analysis since it is the dominant response in a vertical impact environment. The mean peak input acceleration as measured on the VDT carriage for all 45 tests was 9.82 ± 0.07 G and implies that the impact conditions were well controlled during the duration of the testing. The mean and standard deviation data for the four response parameters are also shown in a series of bar charts in Figures 4 through 7.

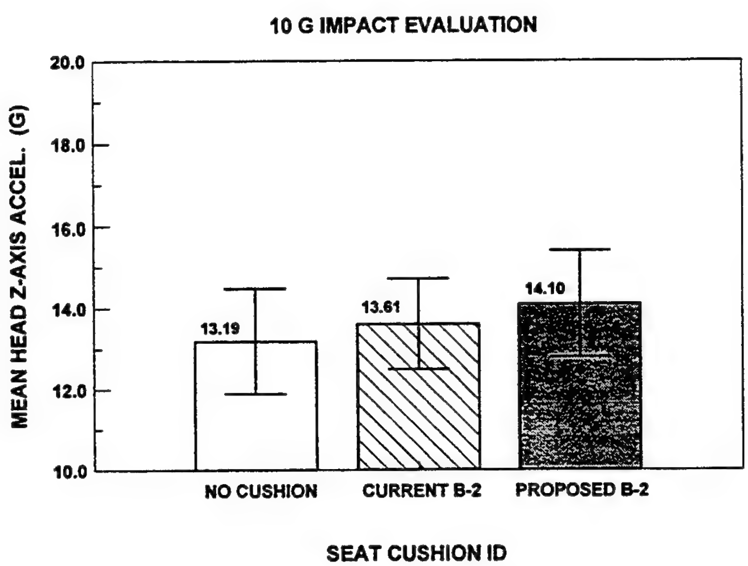

Figure 4. Mean Head Z-Axis Acceleration as a Function of the Seat Cushion Test Condition

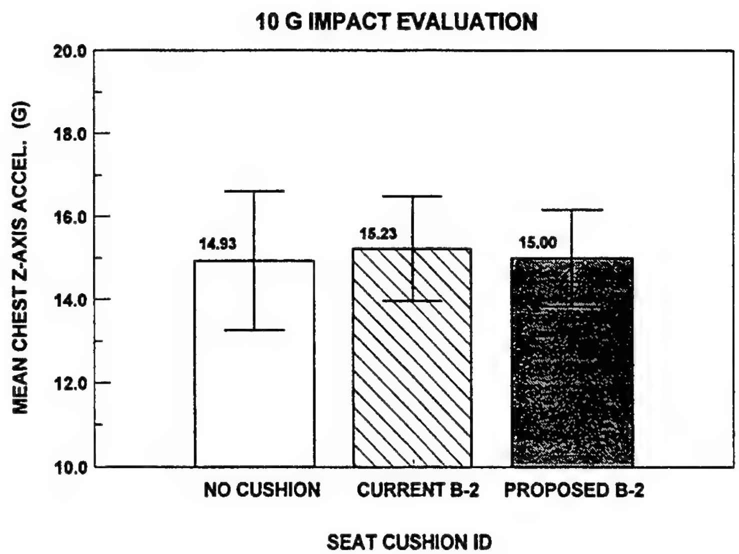

Figure 5. Mean Chest Z-Axis Acceleration as a Function of the Seat Cushion Test Condition

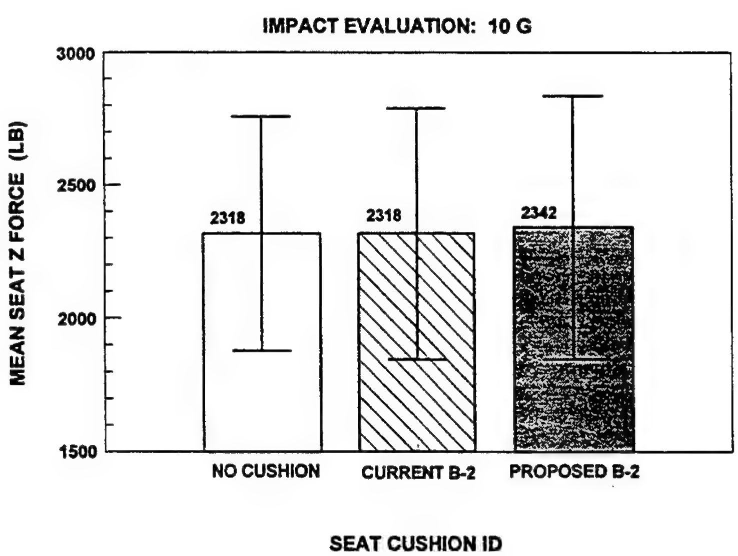

Figure 6. Mean Seat Pan Z-Axis Force as a Function of the Seat Cushion Test Condition

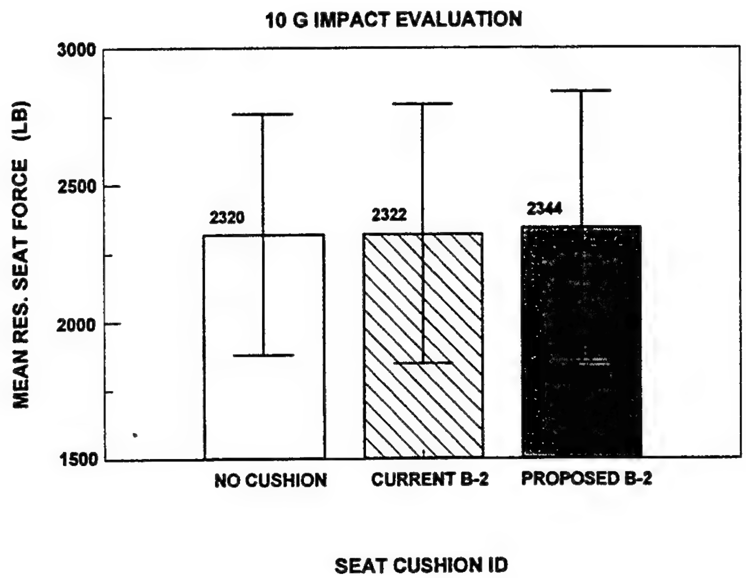

Figure 7. Mean Resultant Seat Pan Force as a Function of the Seat Cushion Test Condition

As shown in Table 3 and in Figures 4 through 7, the mean peak responses for the four evaluated parameters do not change significantly as a function of the cushion condition. In most cases, the cushion responses were equal to or slightly greater than the no cushion condition. The proposed cushion responses were slightly higher for all the parameters except the torso (chest) acceleration which was slightly lower. To determine the statistical significance of the noted trends, the means for the four different test parameters were evaluated as a function of the cushion condition using the paired T-test. This method assumes data come from an approximately normal distribution. The approximate normality of the data sets was verified using probability plots and an evaluation of the skewness factor [5]. The probability plots revealed that the individual response values from the data sets for the four parameters had an

approximate linear relationship with the probability plot position, F_i, which is defined by the following equation:

$$F_i = 100[\frac{(i-0.5)}{n}]$$

where n equals the total number of data points, i equals the rank of the data point from 1 to n. Examples of probability plots for the evaluated parameters are shown in Figures 8 through 11. The skewness factor, g_1, for each data set was compared to a limit range that determines a normal distribution at a confidence level of 0.05. The skewness factor is defined by the following equation:

$$g_1 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^3}{ns^3}$$

where n equals the total number of data points, x_i equals the individual data point, $\bar{x}$ equals the mean value for the particular data set analyzed, and s equals the data set standard deviation. All values were in the required range for normality.

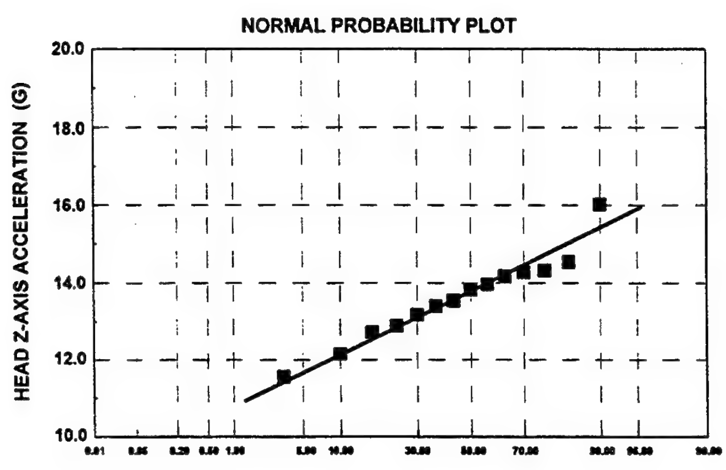

Figure 8. Normal Probability Plot for Cell H Head Z-Axis Acceleration

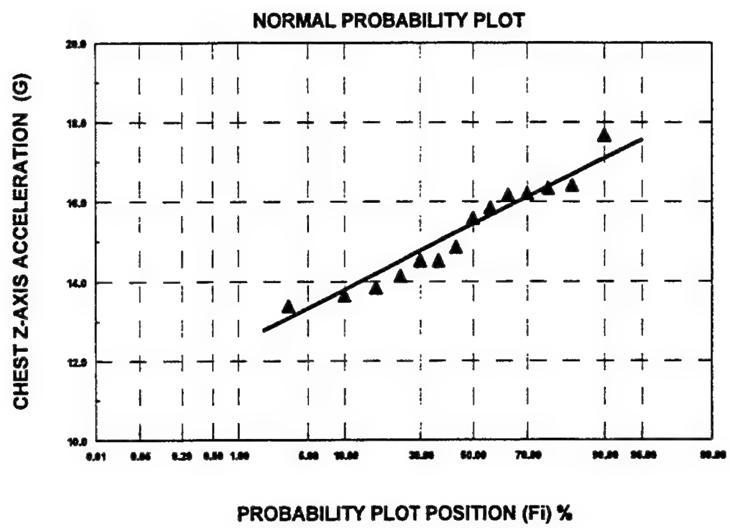

Figure 9. Normal Probability Plot for Cell H Chest Z-Axis Acceleration

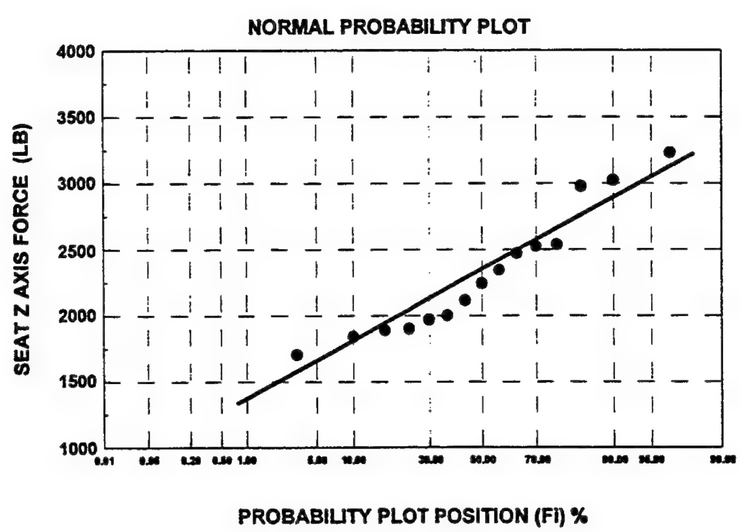

Figure 10. Normal Probability Plot for Cell H Seat Z-Axis Force

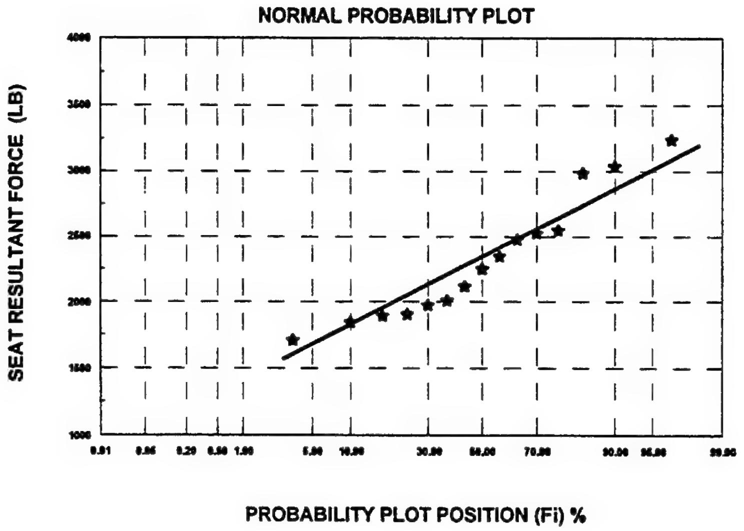

Figure 11. Normal Probability Plot for Cell H Seat Resultant Force

Table 4 shows the results of the paired T-test analysis. Tests were done at a statistical significance level of α=0.05 (95% confidence level). The null hypothesis was that the mean of the differences between the compared parameters is greater than or equal to a defined constant (H_0: $\bar{d} \geq d_0$). The alternative hypothesis was that the mean of the differences between the compared parameters is less than the defined constant (H_1: $\bar{d} < d_0$). The mean difference, $\bar{d}$, is defined as the average differences between two compared test cells for a given parameter (x_1-x_2=d). The constant, d_0, represents an assumed experimental error and was equal to 1.35 G and 1.5 G for the comparisons using the head and chest accelerations (less than 10% of the acceleration means), and was equal to 100 lb for the comparisons using the seat forces (less than 5% of the force means). Comparisons involving Cell H used 14 matched pairs (n=14) due to a deleted outlier in that cell. The other comparison (Cell C to Cell I) used 15 matched pairs (n=15). The critical region for a paired T-test for 14 matched pairs is t less than 2.16 and t greater than 2.16. The critical region for a paired T-test for 15 matched pairs is t less than 2.145 and t greater than 2.145.

Table 4. Paired T-test Evaluation

RESPONSE PARAMETERS	CELL C vs CELL H	CELL C vs CELL I	CELL H vs CELL I
Z-Axis Head Acceleration (G)	t = -3.56 reject H_0	t = -1.06 accept H_0	t = -3.11 reject H_0
Z-Axis Chest Acceleration (G)	t = -2.63 reject H_0	t = -3.94 reject H_0	t = -3.74 reject H_0
Z-Axis Seat Force (lb)	t = -4.37 reject H_0	t = -2.52 reject H_0	t = -4.57 reject H_0
Resultant Seat Force (lb)	t = -4.31 reject H_0	t = -2.49 reject H_0	t = -4.59 reject H_0

Data for the four evaluated response parameters show that in all comparisons but one, the null hypothesis was rejected in favor of the alternative hypothesis. This indicates that the acceleration and force differences were significantly less than the corresponding proposed constants. The exception was the comparison of the head z-axis acceleration between the no-cushion condition and the proposed B-2 seat cushion condition. More important though is the fact that the seat pan loads did not significantly change due to the proposed cushion design within the error defined. Since standard seat cushions tend to increase the biodynamic response during vertical impact, this comparison stresses the importance of the use of rate-dependent foam materials in the design and construction of seat cushions.

CONCLUSIONS

These test results show that the human response to a +Gz impact with the proposed ACES II seat cushion for the B-2 aircraft is not significantly different from the response with no-cushion, or with the current ACES II seat cushion for the B-2 aircraft. The design changes of a contoured seat cushion, use of different foam thickness', and the use of multiple layers of different rate-dependent foams as compared to previous tests with rate-dependent foams, did not increase the current risk of injury associated with the present cushion. The rate-dependent foams performed as expected by limiting and controlling the biodynamic response. In addition, the test subjects noted an enhancement in the sitting comfort when using the proposed seat cushion. This strengthens the conclusion that the proposed seat cushion should improve the overall performance of the ejection seat in terms of comfort and impact protection in the B-2 aircraft.

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APPENDIX A

Test Configuration and Data Acquisition System

TEST CONFIGURATION AND

DATA ACQUISITION SYSTEM FOR THE

EVALUATION OF THE EFFECTS OF GENDER AND

ANTHROPOMETRY ON HUMAN DYNAMIC RESPONSE

AND

B-2 SEAT CUSHION TESTS

DURING +Gz IMPACT ACCELERATION

TEST PROGRAMS

(FIP STUDY)

Prepared under
Contract F33601-96-DJ001

February 1997

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INTRODUCTION

This report was prepared by DynCorp for the Armstrong Laboratory (AL/CFBE) under Air Force Contract F33601-96-DJ001.

The information provided herein describes the test system, seat fixture, restraint configuration, test subjects, test configurations, data acquisition, and the instrumentation procedures that were used in the Evaluation of the Effects of Gender and Anthropometry on Human Dynamic Response and B-2 Seat Cushion Tests During +Gz Impact Accelerations Test Programs (FIP Study). Three hundred sixty-five tests were conducted during the period of 29 April 1996 through 04 November 1996 on the Vertical Deceleration Tower Test system.

1. TEST SYSTEM

The AL/CFBE Vertical Deceleration Tower (VDT), as shown in Figure A-1, was used for all of the tests.

The system consists of a 60-foot vertical steel tower which supports a guide rail system, an impact carriage with a plunger, a hydraulic deceleration device and a test control and safety system. The impact carriage can be raised to a maximum height of 42 feet prior to release. After release, the carriage free falls until the plunger (attached to the undercarriage) enters a water-filled cylinder mounted at the base of the tower. The deceleration profile produced as the plunger displaces the water in the cylinder is determined by the free fall distance, the carriage and test specimen mass, the shape of the plunger and the size of the cylinder orifice. A rubber bumper is used to absorb the final impact as the carriage stops. For these tests, plunger number 102 was mounted under the carriage. Drop height varied from 5'6" to 18'6".

2. SEAT FIXTURE

The VIP seat fixture, as shown in Figure A-2, was used for all of the tests. The seat was designed to withstand vertical impact accelerations up to 50 G. The adjustable seat back was not adjusted during this study as all of the tests were run with a 0 degree seat back angle. The headrest was in-line with the seat back (except for cell J where the headrest was 1" aft of the seat back tangent line). When positioned in the seat, the subject's upper legs were bent perpendicular to the torso with the lower legs bent 90 degrees downward to vertical. The subject was secured in the seat with a standard USAF double shoulder strap and lap belt configuration. The lap belt and shoulder strap were preloaded to 20 ±5 pounds, as required per the test plan.

Each of the subject's lower legs were restrained by a strap that encircled the subject's calf and was attached to the carriage. Another strap crossed the subject's thighs and attached to the seat pan posterior to the knees.

The subject's hands were placed under the thigh restraint. These restraints are illustrated by Figure A-3.

3. TEST SUBJECTS

Both manikins and humans were used as test subjects during this test program.

Two manikins were used for structural and equipment proof tests as follows:

1. One 95th percentile Alderson manikin, designated VIP-95.
2. One Advanced Dynamic Anthropomorphic Manikin (ADAM) representative of the "large" flying population.

The subjects wore either an HGU-55/P flight helmet or the VWI helmet. The VWI helmet system allowed variation of the helmet's inertial properties.

4. TEST CONFIGURATIONS

The test cells used are listed in Table A-1.

Figure A-4 illustrates the cell H (current B-2) and cell I (new B-2) seat cushions.

5. INSTRUMENTATION

The electronic data collected during this test program is described in Sections 5.1 and 5.2. Section 5.1 discusses accelerometers while Section 5.2 discusses load transducers. Section 5.3 discusses the calibration procedures that were used. The measurement instrumentation used in this test program is listed in Tables A-2a through A-2d. These figures designate the manufacturer, type, serial number, sensitivity and other pertinent data on each transducer used. Table A-3 lists the manufacturer's typical transducer specifications.

Accelerometers and load transducers were chosen to provide the optimum resolution over the expected test load range. Full scale data ranges were chosen to provide the expected full scale range plus 50% to assure the capture of peak signals. All transducer bridges were balanced for optimum output prior to the start of the program. The accelerometers were adjusted for the effect of gravity using computer processing software. The component of a 1 G vector in line with the force of gravity that lies along the accelerometer axis was added to each accelerometer.

The accelerometer and load transducer coordinate systems are shown in Figure A-5. The seat coordinate system is right-handed with the z axis parallel to the seat back and positive upward. The x axis is perpendicular to the z axis and positive eyes forward from the subject. The y axis is

Test Cell	G Level	Seat Condition	Helmet System	Notes
A	6	Flat Seat Pan	HGU-55/P	
B	8	Flat Seat Pan	HGU-55/P	
C	10	Flat Seat Pan	HGU-55/P	
C1	10	Flat Seat Pan	HGU-55/P	Cell designation changed from cell C to C1 (tests 3572 and after) due to seat back and headrest being moved 1" forward.
D	10	Flat Seat Pan	VWI Helmet	
E	10	Flat Seat Pan	VWI Helmet 1.5 Lb. at 0"	
F	10	Flat Seat Pan	VWI Helmet 1.5 Lb. at 5" X	
G	10	Flat Seat Pan	VWI Helmet 4.5 Lb. at 2" X	
H	10	Current B-2 Seat Cushion	HGU-55/P	Thoracic accelerometer pack (T1) located on the upper chest.
I	10	New B-2 Seat Cushion	HGU-55/P	Thoracic accelerometer pack (T1) located on the upper chest.
J	10	Flat Seat Pan	VWI Helmet 1.5 Lb. at 0"	Thoracic accelerometer pack (T1) located on the upper chest. Headrest located 1" aft of the seat back tangent line.
ST	15	Flat Seat Pan	HGU-55/P	Structural Proof Test

TABLE A-1: TEST CELL MATRIX

perpendicular to the intersection of the x and z axes according to the right hand rule. The origin of the seat coordinate system is designated as the seat reference point (SRP). The SRP is at the midpoint of the line segment formed by the intersection of the seat pan and seat back. All vector components (for linear accelerations, angular accelerations, forces, moments, etc.) were positive when the vector component (x, y and z) was in the direction of the positive axis.

The linear accelerometers were wired to provide a positive output voltage when the acceleration experienced by the accelerometer was applied in the +x, +y and +z directions, as shown in Figure A-5.

The angular Ry accelerometers were wired to provide a positive output voltage when the angular acceleration experienced by the angular accelerometer was applied in the +y direction according to the right hand rule, as shown in Figure A-5.

The load cells and load links were wired to provide a positive output voltage when the force exerted by the load cell on the subject was applied in the +x, +y or +z direction, as shown in Figure A-5.

All transducers, except the carriage accelerometers and the carriage velocity tachometer, were referenced to the seat coordinate system. The carriage tachometer was wired to provide a positive output voltage during free fall. The carriage accelerometers were referenced to the carriage coordinate system, as shown in Figure A-5.

Carriage velocity was measured using a Globe Industries tachometer Model 22A672-2. The rotor of the tachometer was attached to an aluminum wheel with a rubber "O" ring around its circumference to assure good rail contact. The wheel contacted the track rail and rotated as the carriage moved, producing an output voltage proportional to the velocity.

5.1 Accelerometers

This section describes the accelerometer instrumentation, as required in the AL/CFBE test plan.

Human head accelerations were measured using three Endevco Model 7264-200 linear accelerometers and one Endevco Model 7302B angular (Ry) accelerometer. The accelerometers were mounted to the external edge of a plastic dental bite block. Each subject had their own set of custom fitted dental inserts that were used to support the bite block in their mouth. An infrared LED target was attached directly on the front of the plastic dental bite block. Figure A-6 illustrates the human head accelerometer package.

The chest accelerometer package consisted of three Endevco Model 7264-200 linear accelerometers mounted to a 1/2 x 1/2 x 1/2 inch aluminum block. An Endevco Model 7302A angular (Ry) accelerometer was mounted on a bracket adjacent to the triaxial chest block. The accelerometer packages were inserted into a small protective box to which a length of Velcro fastener strap was attached. The package was placed over the subject's sternum at the level of the xiphoid and was held there by fastening the Velcro strap around the subject's chest. An infrared LED chest target was attached directly to the front of the chest accelerometer package. Figures A-7 and A-8 illustrate the external chest accelerometer package.

Upper thoracic spine (T1) x, y and z accelerations were measured using three Entran EGAXT-100 linear accelerometers. The accelerometers were mounted on a small acrylic base and the accelerometer package was mounted on the

subject with double stick tape. For cells H, I and J, the T1 package was mounted on the upper chest of the subject over the superior end of the sternum. Figures A-9 and A-10 illustrate the T1 accelerometer package.

Carriage z acceleration was measured using one Endevco Model 2262A-200 linear accelerometer. The accelerometer was mounted on a small acrylic block and located behind the seat on the VIP seat structure.

Seat accelerations were measured using three Endevco linear accelerometers: two Models 7264-200 for accelerations in the y and z directions and one model 2264-200 for acceleration in the x direction. The three linear accelerometers were attached to a 1 x 1 x 3/4 inch acrylic block and were mounted near the center of the load cell mounting plate.

5.2 Load Transducers

This section describes the load transducer instrumentation, as required in the AL/CFBE test plan.

The load transducer locations and dimensions are shown in Figures A-11a and A-11c.

Shoulder/anchor forces were measured using one AAMRL/DYN 3D-SW and two Michigan Scientific 4000 triaxial load cells, each capable of measuring forces in the x, y and z directions. The parameters measured are indicated below:

Shoulder x, y and z force
Left lap belt x, y and z force
Right lap belt x, y and z force.

The lap/vertical anchor force triaxial load cells were located on separate brackets mounted on the side of the seat frame parallel to the seat pan.

The shoulder strap force triaxial load cell was mounted on the seat frame between the seat back support plate and the headrest.

Left, right and center seat forces were measured using three load cells and three load links. The three load cells included two Strainsert Model FL2.5U-2SPKT and one Model FL2.5U-2SGKT load cells. The three load links, as shown in Figure A-12, were fabricated by DynCorp using Micro Measurement Model EA-06-062TJ-350 strain gages. All six measurement devices were located under the seat pan support plate. The load links were used for measuring loads in the x and y directions, two in the x direction and one in the y direction. Each load link housed a swivel ball which acted as a coupler between the seat pan and load cell mounting plate. The Strainsert load cells were used for measuring loads in the z direction. The seat pan instrumentation and the lap belt anchor load cells can be seen in Figure A-13.

Upper and lower headrest x forces were each measured using two Strainsert Model FL1U-2SGKT load cells. The load cells were mounted on a rectangular

mounting plate which was attached to the upper seat back. The headrest was attached directly to the load cells. The headrest was adjusted up or down depending on the location of the subject's head. The headrest and shoulder belt anchor load cells can be seen in Figure A-14.

5.3 Calibration

Calibrations were performed before and after testing to confirm the accuracy and functional characteristics of the transducers. Pre-program and post-program calibrations are given in Tables A-4a through A-4c.

The calibration of all Strainsert load cells was performed by the Precision Measurement Equipment Laboratories (PMEL) at Wright-Patterson Air Force Base. PMEL calibrates these devices on a periodic basis and provides current sensitivity and linearity data.

The calibration of the accelerometers was performed by DynCorp using the comparison method (Ensor, 1970). A laboratory standard accelerometer, calibrated on a yearly basis by Endevco with standards traceable to the National Bureau of Standards, and a test accelerometer were mounted on a shaker table. The frequency response and phase shift of the test accelerometer were determined by driving the shaker table with a random noise generator and analyzing the outputs of the accelerometers with a Unisys 386/25 computer using Fourier analysis. The natural frequency and the damping factor of the test accelerometer were determined, recorded and compared to previous calibration data for that test accelerometer. Sensitivities were calculated at 40 G and 100 Hertz. The sensitivity of the test accelerometer was determined by comparing its output to the output of the standard accelerometer.

The angular rate accelerometers were calibrated by DynCorp by comparing their output to the output of a linear standard accelerometer. The angular accelerometer is mounted parallel to the axis of rotation of a Honeywell low inertia D. C. motor. The standard accelerometer is mounted perpendicular to the axis of rotation at a radius of one inch to measure the tangential acceleration. The D. C. motor motion is driven at a constant sinusoidal angular acceleration of 100 Hertz and the sensitivity is calculated by comparing the rms output voltages of the angular and linear accelerometers.

The shoulder/lap triaxial load cells and load links were calibrated by DynCorp. These transducers were calibrated to a laboratory standard load cell in a special test fixture. The sensitivity and linearity of each test load cell were obtained by comparing the output of the test load cell to the output of the laboratory standard under identical loading conditions. The laboratory standard load cell is calibrated by PMEL on a periodic basis.

The velocity wheel is calibrated periodically by DynCorp by rotating the wheel at approximately 2000, 4000 and 6000 revolutions per minute (RPM) and recording both the output voltage and the RPM.

6. DATA ACQUISITION

Data acquisition was controlled by a comparator on the Master Instrumentation Control Unit in the Instrumentation Station. The test was initiated when the comparator countdown clock reached zero. The comparator was set to start data collection at a preselected time.

A reference mark pulse was generated to mark the electronic data and Selspot optical motion data at a preselected time after test initiation to place the reference mark close to the impact point. The reference mark time was used as the start time for data processing of the electronic and Selspot optical motion data.

Prior to each test and prior to placing the subject in the seat, data were recorded to establish a zero reference for all data transducers. These zero reference data were stored separately from the test data and were used in the processing of data.

6.1 Automatic Data Acquisition and Control System (ADACS)

Installation of the ADACS instrumentation is shown in Figure A-15. The three major components of the ADACS system are the power conditioner, signal conditioners and the encoder. A block diagram of the ADACS is shown in Figure A-16. The signal conditioners contain forty-eight amplifiers with programmable gain and filtering.

Bridge excitation for load cells and accelerometers was 10 VDC. Bridge completion and balance resistors were added, as required, to each module input connector.

The forty-eight module output data signals were digitized and encoded into forty-eight 11-bit digital words. Two additional 11-bit synchronization (sync) words were added to the data frame making a fifty word capability.

Three synchronization pulse trains (bit sync, word sync and frame sync) were added to the data frame and sent to the computer via a junction box data cable.

The Data Acquisition, Storage and Analysis Computer Subsystem includes a Gateway 486 computer and the DEC 3000-500 AXP Alpha computer. The Gateway 486 computer communicates with the Real Time Data Acquisition and Control Subsystem using an AT-DIO-32F digital I/O board. The AT-DIO-32F board receives the real-time ADACS binary test data as 16 bit parallel words from the data formatter. The ADACS binary data is stored by the AT-DIO-32F board in the memory of the Gateway 486 using direct memory access (DMA).

The Gateway 486 computer is an IBM compatible PC with a Windows 95 Operating System. The ADACS test data is acquired using a data collection program written using the C programming language. The data collection program acquires the ADACS test data using the AT-DIO-32F digital I/O board, reformats the data for the DEC 3000-500 processing software, and writes the result to a binary data file. The program includes options to compute and

store zero reference voltage values, collect and store a binary zero reference data file, compute and display preload values, and collect and store binary test data.

The data collection program transfers the ADACS test data from memory to a temporary ram disk file. The data is then reformatted to match the format of the ADACS test data that was collected using the BDC board in the PDP 11/34 computer. This allows the data to be analyzed using the same DEC 3000-500 AXP Alpha analysis software that was used to analyze the ADACS test data from the PDP 11/34.

The Gateway 486 computer communicates with the DEC 3000-500 AXP Alpha computer through a thin wire Ethernet network. The test data are transferred from the Gateway 486 computer to the DEC 3000-500 AXP Alpha computer through the Ethernet network and output to optical disk for permanent storage. The interrelationships among the data acquisition and storage equipment are shown in Figure A-17.

The test data can be reviewed immediately after each test by using the "quick look" SCAN routine. SCAN produces a plot of the test data for each channel in engineering units as a function of time. SCAN determines the minimum and maximum values for each channel and outputs a summary sheet containing the results. It also calculates the rise time and pulse duration for the carriage acceleration, and creates a text data base file containing significant test parameters.

6.2 Selspot Motion Analysis System

The Selspot Motion Analysis System utilizes photosensitive cameras to track the motion of infrared LED targets attached to different points on the test fixture. The three-dimensional motion of the LEDs is determined by combining the images from two different Selspot cameras. The two Selspot cameras were mounted onboard the carriage. The side camera was a Selspot Model 412 (S/N 457) and the oblique camera was a Selspot Model 412 (S/N 458). Both cameras had 24 mm lenses. The Selspot cameras are shown in Figure A-18.

The Selspot System includes a ZCM 1450 video monitor and a Zenith Data Systems Z Select 100 microcomputer with 16 Mbyte RAM, HW VCU-2 VME Control Unit II, a camera interface module (MCIM), a 3.5" 1.44 Mbyte floppy disk drive, and a 404 Mbyte hard disk drive. The Selspot Computer System is shown in Figure A-19. The microcomputer uses the MS Windows 95 operating system. The Selspot data collection and processing are performed by the Selspot MULTILAB System software. The Selspot test data is transferred over the network to the optical disk drive on the DEC 3000-500 AXP Alpha computer for permanent storage.

The Selspot System was calibrated by determining the camera locations and orientations prior to the start of the test program. The camera locations and orientations were referenced to the coordinate system of the Position Reference Structure (PRS). The PRS is shaped as a tetrahedron with

reference LEDs 1, 2, 3 and 4 located at the vertices. The PRS is shown in Figure A-20.

For cells A, B, C, C1, H and I, motion of the subjects' helmet top, helmet bottom, bite bar, neck, shoulder and chest were quantified by tracking the motion of six subject-mounted LEDs. For cells D, E, F, G and J, motion of the subjects' helmet top, helmet bottom, bite bar, helmet brow, shoulder and chest were quantified by tracking the motion of six subject-mounted LEDs. Four reference LEDs were placed on the test fixture. The locations of the LEDs generally followed the guidelines provided in "Film Analysis Guides for Dynamic Studies of Test Subjects, Recommended Practice (SAE J138, March 1980)." Figures A-21 through A-24 identify the LED target locations.

Selspot data was collected from the six moving and four reference LEDs at a 500 Hz sample rate during the impact. Data collection started at T = -2 seconds for 5 seconds. The data was processed starting at the reference mark time for 600 milliseconds on the Selspot Motion Analysis System, shown in the block diagram in Figure A-25. The camera image coordinates were corrected for camera vibration, converted into three-dimensional coordinates, and transformed into the seat coordinate seat.

A Kodak Ektapro 1000 video system was also used to provide onboard coverage of each test. This video recorder and display unit is capable of recording high-speed motion up to a rate of 10000 frames per second. The Kodak Ektapro 1000 Video System (less camera) is shown in Figure A-26. Immediate replay of the impact is possible in real time or in slow motion.

7. PROCESSING PROGRAMS

The executable image for the ADACS processing program is located in directory PROCESS of the DEC 3000-500 AXP Alpha computer and the test data is assumed to be stored in logical directory DATADIR. All plots and the test summary sheet are output to the LN03 laser printer. The test base file is output to directory PROCESS.

The Fortran program that processes the test data for the FIP Study (Vertical Deceleration Tower System) is named FIPVDT. The character string 'FIP' identifies the study and 'VDT' identifies the system (Vertical Deceleration Tower). Logical directory DATADIR is assumed to contain a test data file named '<test no>D.VDT' and a sensitivity file named '<test no>S.VDT'. FIPVDT assumes that the test data was collected using the ADACS data acquisition system.

FIPVDT requests the user to enter the total number of tests to be processed and the test number for each test. The default test parameters are retrieved from the test sensitivity file and displayed as a menu on the screen. The user may specify new values for any of the displayed test parameters. The test parameters include the subject ID, weight, age, height and sitting height. Additional parameters include the cell type, nominal G level, subject type (manikin or human) and belt preload status (computed

or not computed). If the belt preloads were computed, then the shoulder and lap preloads are also displayed.

FIPVDT generates time histories for the carriage z axis acceleration; the carriage velocity; the seat x, y and z axis accelerations; the seat z axis DRI; the head x, y, z, Ry and resultant accelerations; the chest x, y, z, Ry and resultant accelerations; and the T1 x, y, z and resultant accelerations.

Time histories are also generated for the upper and lower headrest x forces and their sum; the shoulder x, y, z and resultant forces; the left lap x, y, z and resultant forces; the right lap x, y, z and resultant forces; the left, right and center seat z forces, and their sum; the left and right seat x axis forces, and their sum; the seat y axis force; the seat resultant; the tare corrected seat resultant; and the tare corrected seat z axis sum. Values for the preimpact level and the extrema for each time history are stored in the test base file and printed out as a summary sheet for each test. The time histories are also plotted.

All of the data channels are filtered using a 60 Hz FIR filter. The first 50 points following the reference mark are averaged to compute the zero offset levels for the linear and angular accelerometers. The zero offset levels are subtracted from the accelerometer time histories. The x and z axis components of the upper spine (T1) accelerometer are rotated to compensate for the accelerometer angle.

The output from FIPVDT is controlled by the parameter file 'FIPVDT.SET'. The parameter file can be used to enable or disable the generation of the data base summary file, the LN03 printer summary sheets, the LN03 plots, and text files containing channel time histories. The parameter file also allows the user to specify the analysis window time, the plot time increment, and the plot orientation. This allows the user to rerun the analysis without regenerating unnecessary printer output and text files.

The parameter file 'FIPVDT.LST' is used to control the creation of the text files containing channel time histories. The time histories files are created with the filename '<Test Number>VDT.L<File Number>'. The file number starts at one and is incremented for each additional time history file that is created.

FIPVDT uses a different method to calculate the rise time and duration than was used on previous Vertical Deceleration Tower System test programs. FIPVDT searches for the rising edge 90% G level by starting at the peak acceleration time and searching backward in time. The 90% G level represents the level corresponding to 90% of the difference between the peak G level and a 25 ms average level calculated at the start of the impact event window. FIPVDT searches for the falling edge 90% G level by starting at the peak acceleration time and searching forward in time. The rise time is defined to be the average of the rising and falling edge 90% G level times minus the start of impact time. The start of impact time is the time at which the G level reaches 0.5 G.

The 3 G level on the falling edge is found by starting at the 90% falling edge time and searching forward in time. The end of impact time is defined to be the time at which a line drawn through the 90% G level point and the 3 G level point intersects 0.5 G. The duration is the end of impact time minus the start of impact time.

DYNCORP DIGITAL INSTRUMENTATION REQUIREMENTS

PROGRAM EVALUATION OF THE EFFECTS OF GENDER AND ANTHROPOMETRY ON HUMAN DYNAMIC RESPONSE DURING +Gz IMPACT (FIP STUDY)

DATES: 29-APR-96 THRU 04-NOV-96

FACILITY VERTICAL DECELERATION TOWER

RUN NUMBERS: 3465 - 3829

DATA CHAN	DATA POINT	XDUCER MFG & TYPE	SERIAL NUMBER	XDUCER SENS	EXCITE VOLT CHAN	FILTER SERIES S/N	AMP GAIN S/N	SAMPLE RATE FORMAT	FULL SCALE SENS	FILTER HZ	XDUCER ZERO RANGE	BRIDGE BALANCE RES	BRIDGE COMP RES	SPECIAL NOTATIONS
1	CARRIAGE z ACCEL.	ENDEVCO 2262A-200	KJ75	3.404 mv/G	10.00 1	60 1	10 32	1K 1	73.4G	120	2.5V +5.0 0.0	-	-	
2	SEAT x ACCEL.	ENDEVCO 2264-200	CH74	2.985 mv/G	10.00 2	60 2	50 22	1K 1	16.8G	120	2.5V +5.0 0.0	99K +IN TO GND	1.5K	
3	SEAT y ACCEL.	ENDEVCO 7264-200	CC79H	3.310 mv/G	10.00 3	60 3	50 3	1K 1	15.1G	120	2.5V +5.0 0.0	-	1.5K	
4	SEAT z ACCEL.	ENDEVCO 7264-200	BY77H	3.358 mv/G	10.00 4	60 4	10 10	1K 1	74.4G	120	2.5V +5.0 0.0	142K +IN TO GND	1.5K	
5	HEAD x ACCEL.	ENDEVCO 7264-200	CD85H	2.673 mv/G	10.00 5	60 5	50 24	1K 1	18.7G	120	2.5V +5.0 0.0	-	1.5K	
6	HEAD y ACCEL.	ENDEVCO 7264-200	CL83H	-2.897 mv/G	10.00 6	60 6	50 12	1K 1	17.3G	120	2.5V +5.0 0.0	-	1.5K	USE NEGATIVE SENS.
7	HEAD z ACCEL.	ENDEVCO 7264-200	CL86H	-2.869 mv/G	10.00 7	60 7	25 9	1K 1	34.9G	120	2.5V +5.0 0.0	-	1.5K	USE NEGATIVE SENS.
8	HEAD Ry ACCEL.	ENDEVCO 7302B	A20Y	3.453 µv/RAD/SEC	10.00 8	60 8	201 4	1K 1	3602 RAD/SEC	120	2.5V +5.0 0.0	-	-	
9	CHEST X ACCEL.	ENDEVCO 7264-200	BH76H	3.220 mv/G	10.00 9	60 9	25 11	1K 1	31.1G	120	2.5V +5.0 0.0	-	1.5K	

NOTE: T-1 Pack located above chest pack area for Cell H, I & J tests.

TABLE A-2a: DIGITAL INSTRUMENTATION REQUIREMENTS (PAGE 1 OF 4)

DYNCORP DIGITAL INSTRUMENTATION REQUIREMENTS

PROGRAM EVALUATION OF THE EFFECTS OF GENDER AND ANTHROPOMETRY ON HUMAN DYNAMIC RESPONSE DURING +Gz IMPACT (FIP STUDY)

DATES: 29-APR-96 THRU 04-NOV-96

FACILITY VERTICAL DECELERATION TOWER

RUN NUMBERS: 3465 - 3829

DATA CHAN	DATA POINT	XDUCER MFG & TYPE	SERIAL NUMBER	XDUCER SENS	EXCITE VOLT CHAN	FILTER SERIES S/N	AMP GAIN S/N	SAMPLE RATE FORMAT	FULL SCALE SENS	FILTER HZ	XDUCER ZERO RANGE	BRIDGE BALANCE RES	BRIDGE COMP RES	SPECIAL NOTATIONS
10	CHEST y ACCEL.	ENDEVCO 7264-200	BH81H	3.265 mv/G	10.00 10	60 10	25 31	1K 1	30.6G	120	2.5V +5.0 0.0	-	1.5K	
11	CHEST z ACCEL.	ENDEVCO 7264-200	BH87H	2.985 mv/G	10.00 11	60 11	25 35	1K 1	33.5G	120	2.5V +5.0 0.0	105K +IN TO GND	1.5K	
12	CHEST Ry ACCEL.	ENDEVCO 7302A	AB12	4.27 mv/RAD/SEC²	10.00 12	60 12	201 2	1K 1	2913 RAD/SEC²	120	2.5V +5.0 0.0	-	-	
13	LEFT SEAT z LOAD	STRAINSERT FL2.5U-2SGKT	3294-1	8.06 µv/LB	10.00 13	60 13	201 13	1K 1	1543 LB	120	2.5V +5.0 0.0	-	-	
14	RIGHT SEAT z LOAD	STRAINSERT FL2.5U-2SPKT	3294-2	8.06 µv/LB	10.00 14	60 14	201 11	1K 1	1543 LB	120	2.5V +5.0 0.0	-	-	
15	CENTER SEAT z LOAD	STRAINSERT FL2.5U-2SPKT	3294-4	8.12 µv/LB	10.00 15	60 15	100 29	1K 1	3079 LB	120	2.5V +5.0 0.0	-	-	
16	LEFT SEAT x LOAD	AAMRL/DYN EA-06-062TJ-350	1	10.57 µv/LB	10.00 16	60 16	402 1	1K 1	588 LB	120	2.5V +5.0 0.0	22.7K +IN TO GND	-	
17	RIGHT SEAT x LOAD	AAMRL/DYN EA-06-062TJ-350	2	10.37 µv/LB	10.00 17	60 17	402 2	1K 1	600 LB	120	2.5V +5.0 0.0	4.7K +IN TO GND	-	
18	SEAT y LOAD	AAMRL/DYN EA-06-062TJ-350	3A	10.60 µv/LB	10.00 18	60 18	201 12	1K 1	1152 LB	120	2.5V +5.0 0.0	27K -IN TO GND	-	

TABLE A-2b: DIGITAL INSTRUMENTATION REQUIREMENTS (PAGE 2 OF 4)

DYNCORP DIGITAL INSTRUMENTATION REQUIREMENTS

PROGRAM EVALUATION OF THE EFFECTS OF GENDER AND ANTHROPOMETRY ON HUMAN DYNAMIC RESPONSE DURING +Gz IMPACT (FIP STUDY)

DATES: 29-APR-96 THRU 04-NOV-96

FACILITY VERTICAL DECELERATION TOWER

RUN NUMBERS: 3465 - 3829

DATA CHAN	DATA POINT	XDUCER MFG & TYPE	SERIAL NUMBER	XDUCER SENS	EXCITE VOLT / CHAN	FILTER SERIES / S/N	AMP GAIN / S/N	SAMPLE RATE / FORMAT	FULL SCALE SENS	FILTER HZ	XDUCER ZERO / RANGE	BRIDGE BALANCE RES	BRIDGE COMP RES	SPECIAL NOTATIONS
19	LEFT LAP x LOAD	MICHIGAN-SCIEN. 4000	2X	13.95 µv/LB	10.00 / 19	60 / 19	201 / 16	1K / 1	892 LB	120	2.5V / +5.0 / 0.0	-	-	
20	LEFT LAP y LOAD	MICHIGAN-SCIEN. 4000	2Y	13.37 µv/LB	10.00 / 20	60 / 20	201 / 15	1K / 1	930 LB	120	2.5V / +5.0 / 0.0	-	-	
21	LEFT LAP z LOAD	MICHIGAN-SCIEN. 4000	2Z	13.52 µv/LB	10.00 / 21	60 / 21	100 / 8	1K / 1	1849 LB	120	2.5V / +5.0 / 0.0	-	-	
22	RIGHT LAP x LOAD	MICHIGAN-SCIEN. 4000	3X	14.11 µv/LB	10.00 / 22	60 / 22	201 / 10	1K / 1	881 LB	120	2.5V / +5.0 / 0.0	-	-	
23	RIGHT LAP y LOAD	MICHIGAN-SCIEN. 4000	3Y	13.54 µv/LB	10.00 / 23	60 / 38	201 / 5	1K / 1	919 LB	120	2.5V / +5.0 / 0.0	-	-	
24	RIGHT LAP z LOAD	MICHIGAN-SCIEN. 4000	3Z	13.54 µv/LB	10.00 / 24	60 / 24	100 / 18	1K / 1	1846 LB	120	2.5V / +5.0 / 0.0	-	-	
25	SHOULDER x LOAD	GM/DYN 3D-SW	15Z	6.26 µv/LB	10.00 / 25	60 / 25	402 / 4	1K / 1	993 LB	120	2.5V / +5.0 / 0.0	-	-	
26	SHOULDER y LOAD	GM/DYN 3D-SW	15Y	5.37 µv/LB	10.00 / 26	60 / 26	800 / 1	1K / 1	582 LB	120	2.5V / +5.0 / 0.0	18.7K -IN TO GND	-	
27	SHOULDER z LOAD	GM/DYN 3D-SW	15X	5.37 µv/LB	10.00 / 27	60 / 27	402 / 9	1K / 1	1158 LB	120	2.5V / +5.0 / 0.0	16.7K -IN TO GND	-	

TABLE A-2c: DIGITAL INSTRUMENTATION REQUIREMENTS (PAGE 3 OF 4)

DYNCORP DIGITAL INSTRUMENTATION REQUIREMENTS

PROGRAM EVALUATION OF THE EFFECTS OF GENDER AND ANTHROPOMETRY ON HUMAN DYNAMIC RESPONSE DURING +Gz IMPACT (FIP STUDY)

DATES: 29-APR-96 THRU 04-NOV-96

FACILITY VERTICAL DECELERATION TOWER

RUN NUMBERS: 3465 - 3829

DATA CHAN	DATA POINT	XDUCER MFG & TYPE	SERIAL NUMBER	XDUCER SENS	EXCITE VOLT CHAN	FILTER SERIES S/N	AMP GAIN S/N	SAMPLE RATE FORMAT	FULL SCALE SENS	FILTER HZ	XDUCER ZERO RANGE	BRIDGE BALANCE RES	BRIDGE COMP RES	SPECIAL NOTATIONS
28	TI x ACCEL.	ENTRAN EGAXT-100	87E87D29-V11	0.991 mv/G	10.00 28	60 28	100 21	1K 1	25.2G	120	2.5V +5.0 0.0	-	-	
29	TI y ACCEL.	ENTRAN EGAXT-100	87E87D29-V12	1.009 mv/G	10.00 29	60 29	100 25	1K 1	24.8G	120	2.5V +5.0 0.0	-	-	
30	TI z ACCEL.	ENTRAN EGAXT-100	87E87D29-V13	0.987 mv/G	10.00 30	60 30	50 32	1K 1	50.7G	120	2.5V +5.0 0.0	-	-	
31	HEADREST UPPER LOAD X	STRAINSERT FL1U-2SGKT	203	19.91 μv/LB	10 31	60 31	201 19	1K 1	625 LB	120	2.5V +5.0 0.0	-	-	
32	HEADREST LOWER LOAD X	STRAINSERT FL1U-2SGKT	218	20.10 μv/LB	10 32	60 32	201 14	1K 1	619 LB	120	2.5V +5.0 0.0	-	-	
45	EVENT	-	-	1.0 VOLT	- 45	1000 3	2.5 21	1K 1	2.5 VOLT	2000	2.5V +5.0 0.0	-	-	PATCHED VIA ANALOG 1
46	T = 0 PULSE	-	-	1.0 VOLT	- 46	1000 12	1 -	1K 1	2.5 VOLT	2000	2.5 +5.0 0.0	-	-	PATCHED VIA HIGH LEVEL BOARD PATCH
47	VELOCITY	GLOBE 22A672-2	4	0.06405 VOLTS/FT/SEC	- 47	30 1	1 -	1K 1	78.1 F/S	60	0 +5.0 0.0	-	-	RAW SENSITIVITY = 0.1857 V/REV/SEC; (12IN/FT/4.56IN/REV) X 0.1857 V/REV/SEC = 0.4887 V/FT/SEC; ATTEN @7.63 ∴ 0.4887V/FT(1/7.63) = 0.06405 V/FT/SEC

TABLE A-2d: DIGITAL INSTRUMENTATION REQUIREMENTS (PAGE 4 OF 4)

MANUFACTURER	MODEL	RANGE	SENSITIVITY (mv)	RESONANCE FREQ (Hz)	FREQUENCY RESPONSE (Hz)	EXCITATION (Volt)	2 ARM or 4 ARM	ADDITIONAL NOTES
ENDEVCO	2262A-200	± 200 G	2.5/G	7000	0-2000	10	4 ARM	LINEAR ACCELEROMETER
ENDEVCO	2264-200	± 200 G	2.5/G	4700	0-1200	10	2 ARM	LINEAR ACCELEROMETER
ENDEVCO	7302A	± 50,000 RAD/SEC^2	.0055 /RAD/SEC^2	2500	1-600	10	4 ARM	ANGULAR ACCELEROMETER X10 OVERRANGE
ENDEVCO	7302B	± 50,000 RAD/SEC^2	.004 /RAD/SEC^2	3000	1-600	10	4 ARM	ANGULAR ACCELEROMETER X10 OVERRANGE
ENDEVCO	7264-200	± 200 G	2.5/G	6000	0-1200	10	2 ARM	LINEAR ACCELEROMETER
ENTRAN	EGAXT-100	± 100 G	2.0/G	1700	600	10	4 ARM	LINEAR ACCELEROMETER
STRAINSERT	FL2.5U-2SPKT & 2SGKT	± 2500 LB	.008/LB	3600	0-2000	10	4 ARM	LOAD CELL 15 V MAX EXC. 5 K LB MAX. OVERRANGE
STRAINSERT	FL1U-2SGKT	± 1000 LB	.020/LB	3600	0-2000	10	4 ARM	LOAD CELL 15 V MAX EXC. 2 K LB MAX. OVERRANGE

TABLE A-3: TYPICAL TRANSDUCER SPECIFICATIONS

DYNCORP PROGRAM CALIBRATION LOG

PROGRAM EVALUATION OF THE EFFECTS OF GENDER AND ANTHROPOMETRY ON HUMAN DYNAMIC RESPONSE DURING +Gz IMPACT (FIP STUDY)

DATES: 29-APR-96 THRU 04-NOV-96

FACILITY VERTICAL DECELERATION TOWER

RUN NUMBERS: 3465 - 3829

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE - CAL		POST - CAL		%CHANGE	NOTES
			DATE	SENS	DATE	SENS		
CARRIAGE Z ACCEL.	ENDEVCO 2262A-200	KJ75	08-FEB-96	3.404 mv/G	15-NOV-96	3.408 mv/G	+0.1	
SEAT X ACCEL.	ENDEVCO 2264-200	CH74	27-MAR-96	2.985 mv/G	14-NOV-96	2.988 mv/G	+0.1	
SEAT Y ACCEL.	ENDEVCO 7264-200	CC79H	27-MAR-96	3.310 mv/G	14-NOV-96	3.310 mv/G	0	
SEAT Z ACCEL.	ENDEVCO 7264-200	BY77H	27-MAR-96	3.358 mv/G	14-NOV-96	3.361 mv/G	+0.1	
HEAD X ACCEL.	ENDEVCO 7264-200	CD85H	19-APR-96	2.673 mv/G	15-NOV-96	2.681 mv/G	+0.3	
HEAD Y ACCEL.	ENDEVCO 7264-200	CL83H	19-APR-96	2.897 mv/G	15-NOV-96	2.907 mv/G	+0.3	
HEAD Z ACCEL.	ENDEVCO 7264-200	CL86H	19-APR-96	2.869 mv/G	15-NOV-96	2.875 mv/G	+0.2	
HEAD Ry ACCEL.	ENDEVCO 7302B	A20Y	18-APR-96	3.453 μv/RAD/SEC²	15-NOV-96	3.422 μv/RAD/SEC²	-0.9	
CHEST X ACCEL.	ENDEVCO 7264-200	BH76H	30-MAR-95	3.220 mv/G	15-NOV-96	3.230 mv/G	+0.3	
CHEST Y ACCEL.	ENDEVCO 7264-200	BH81H	30-MAR-95	3.265 mv/G	15-NOV-96	3.272 mv/G	+0.2	
CHEST Z ACCEL.	ENDEVCO 7264-200	BH87H	30-MAR-95	2.985 mv/G	15-NOV-96	2.992 mv/G	+0.2	
CHEST Ry ACCEL.	ENDEVCO 7302	AB12	19-ARP-96	4.27 μv/RAD/SEC²	15-NOV-96	4.27 μv/RAD/SEC²	0	
LEFT SEAT Z LOAD	STRAINSERT FL2.5U-2SGKT	3294-1	22-FEB-96	8.06 μv/LB	-	-	-	CALIBRATED PERIODICALLY BY PMEL.
RIGHT SEAT Z LOAD	STRAINSERT FL2.5U-2SPKT	3294-2	22-FEB-96	8.06 μv/LB	-	-	-	CALIBRATED PERIODICALLY BY PMEL.

TABLE A-4a: TRANSDUCER PRE- AND POST-CALIBRATION (PAGE 1 OF 3)

DYNCORP PROGRAM CALIBRATION LOG

PROGRAM EVALUATION OF THE EFFECTS OF GENDER AND ANTHROPOMETRY ON HUMAN DYNAMIC RESPONSE DURING +Gz IMPACT (FIP STUDY)

DATES: 29-APR-96 THRU 04-NOV-96

FACILITY VERTICAL DECELERATION TOWER

RUN NUMBERS: 3465 - 3829

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE - CAL DATE	PRE - CAL SENS	POST - CAL DATE	POST - CAL SENS	%CHANGE	NOTES
CENTER SEAT Z LOAD	STRAINSERT FL2.5U-2SPKT	3294-4	23-FEB-96	8.12 µv/LB	-	-	-	CALIBRATED PERIODICALLY BY PMEL.
LEFT SEAT X LOAD	AAMRL/DYN EA-06-062TJ-350	1	11-JAN-95	10.57 µv/LB	12-NOV-96	10.41 µv/LB	-1.5	
RIGHT SEAT X LOAD	AAMRL/DYN EA-06-062TJ-350	2	11-JAN-95	10.37 µv/LB	12-NOV-96	10.21 µv/LB	-1.5	
SEAT Y LOAD	AAMRL/DYN EA-06-062TJ-350	3A	11-JAN-95	10.80 µv/LB	12-NOV-96	10.66 µv/LB	-1.3	
LEFT LAP X LOAD	MICHIGAN-SCIENTIFIC 4000	2X	04-APR-96	13.95 µv/LB	12-NOV-96	13.78 µv/LB	-1.2	
LEFT LAP Y LOAD	MICHIGAN-SCIENTIFIC 4000	2Y	04-APR-96	13.37 µv/LB	12-NOV-96	13.21 µv/LB	-1.2	
LEFT LAP Z LOAD	MICHIGAN-SCIENTIFIC 4000	2Z	04-APR-96	13.52 µv/LB	12-NOV-96	13.33 µv/LB	-1.4	
RIGHT LAP X LOAD	MICHIGAN-SCIENTIFIC 4000	3X	04-APR-96	14.11 µv/LB	12-NOV-96	13.93 µv/LB	-1.3	
RIGHT LAP Y LOAD	MICHIGAN-SCIENTIFIC 4000	3Y	04-APR-96	13.54 µv/LB	12-NOV-96	13.32 µv/LB	-1.3	
RIGHT LAP Z LOAD	MICHIGAN-SCIENTIFIC 4000	3Z	04-APR-96	13.54 µv/LB	12-NOV-96	13.43 µv/LB	-0.8	
SHOULDER X LOAD	GM/DYN 3D-SW	15Z	03-MAY-95	6.26 µv/LB	12-NOV-96	6.20 µv/LB	-1.0	
SHOULDER Y LOAD	GM/DYN 3D-SW	15Y	03-MAY-95	5.37 µv/LB	12-NOV-96	5.38 µv/LB	+0.2	
SHOULDER Z LOAD	GM/DYN 3D-SW	15X	03-MAY-95	5.37 µv/LB	12-NOV-96	5.35 µv/LB	-0.4	
T1 X ACCEL.	ENTRAN EGAXT-100	87E87D29-V-11	19-APR-96	0.991 mv/G	14-NOV-96	0.995 mv/G	+0.4	

TABLE A-4b: TRANSDUCER PRE- AND POST-CALIBRATION (PAGE 2 OF 3)

DYNCORP PROGRAM CALIBRATION LOG

PROGRAM: EVALUATION OF THE EFFECTS OF GENDER AND ANTHROPOMETRY ON HUMAN DYNAMIC RESPONSE DURING +Gz IMPACT (FIP STUDY)

DATES: 29-APR-96 THRU 04-NOV-96

FACILITY: VERTICAL DECELERATION TOWER

RUN NUMBERS: 3465 - 3829

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE - CAL		POST - CAL		%CHANGE	NOTES
			DATE	SENS	DATE	SENS		
T1 Y ACCEL.	ENTRAN EGAXT-100	87E87D29-V-12	19-APR-96	1.009 mv/G	14-NOV-96	1.009 mv/G	0	
T1 Z ACCEL.	ENTRAN EGAXT-100	87E87D29-V-13	19-APR-96	0.987 mv/G	14-NOV-96	0.987 mv/G	+0.4	
HEADREST UPPER LOAD X	STRAINSERT FL1U-2SGKT	203	29-OCT-92	19.91 µv/LB	-	-	-	CALIBRATED PERIODICALLY BY PMEL.
HEADREST LOWER LOAD X	STRAINSERT FL1U-2SGKT	218	29-OCT-92	20.10 µv/LB	-	-	-	CALIBRATED PERIODICALLY BY PMEL.
VELOCITY	GLOBE 22A672-2	4	12-OCT-95	0.06405 VOLTS/FT/SEC	-	-	-	RAW SENSITIVITY = 0.1857 V/REV/SEC; 0.4887 V/REV/SEC FOR 4.56" CIR.; ATTENUATOR = 7.63; 0.4887 V/FT ÷ 7.63 = 0.06405 V/FT/SEC; CALIBRATED PERIODICALLY BY DYNCORP.

TABLE A-4c: TRANSDUCER PRE- AND POST-CALIBRATION (PAGE 3 OF 3)

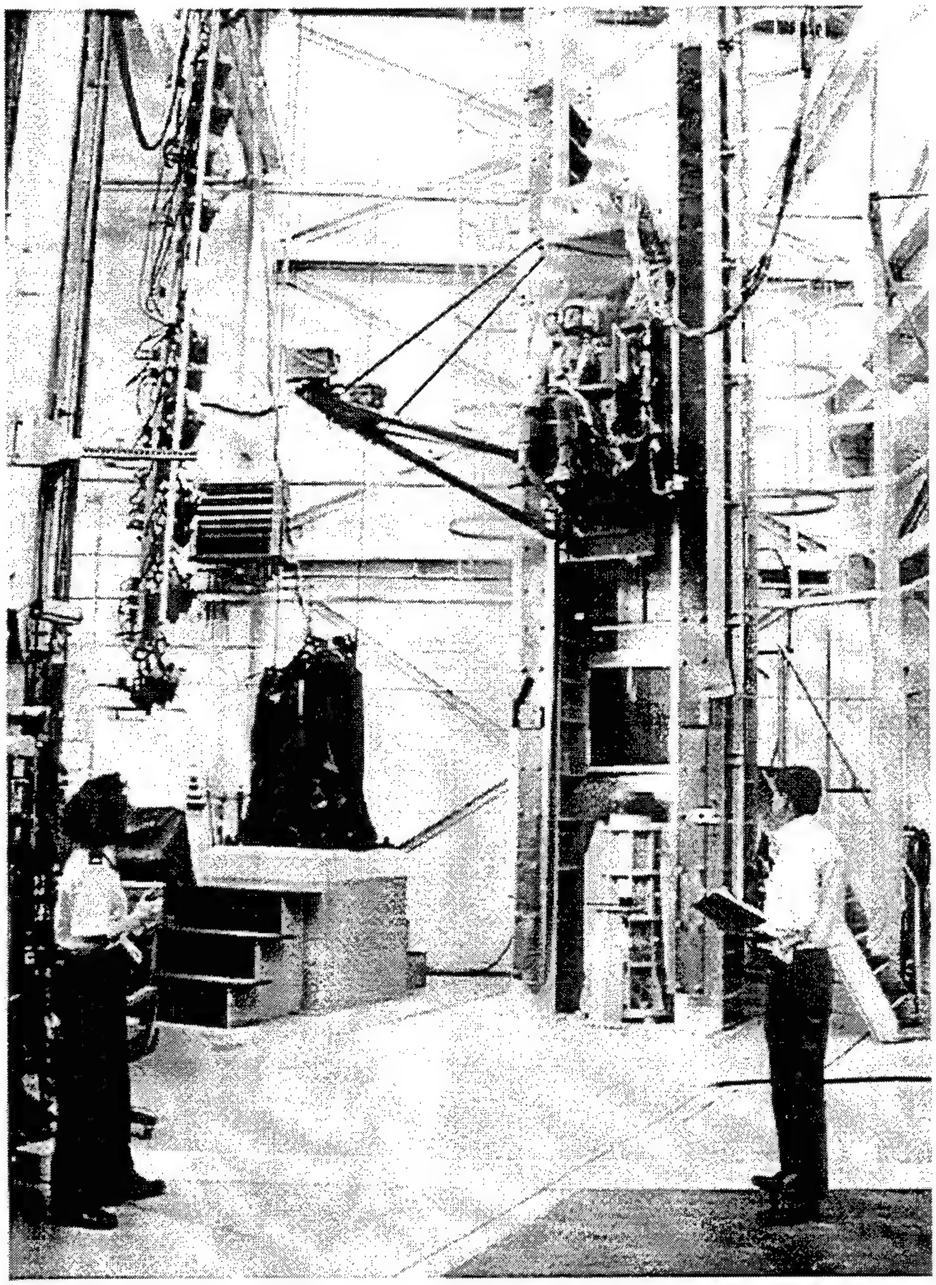


FIGURE A-1: AL/CFBE VERTICAL DECELERATION TOWER

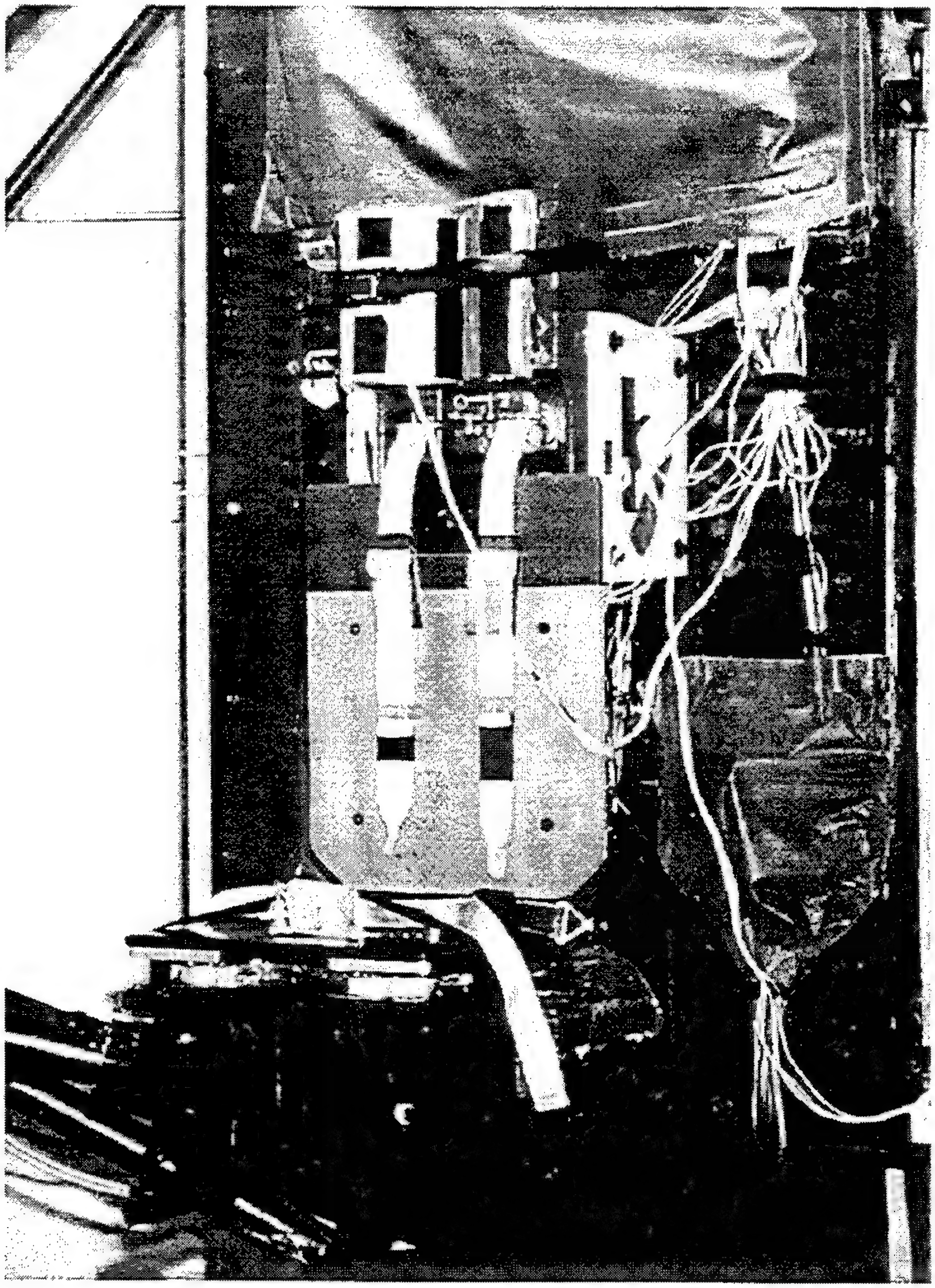


FIGURE A-2: VIP SEAT FIXTURE

FIGURE A-3: SUBJECT LEG AND THIGH RESTRAINTS

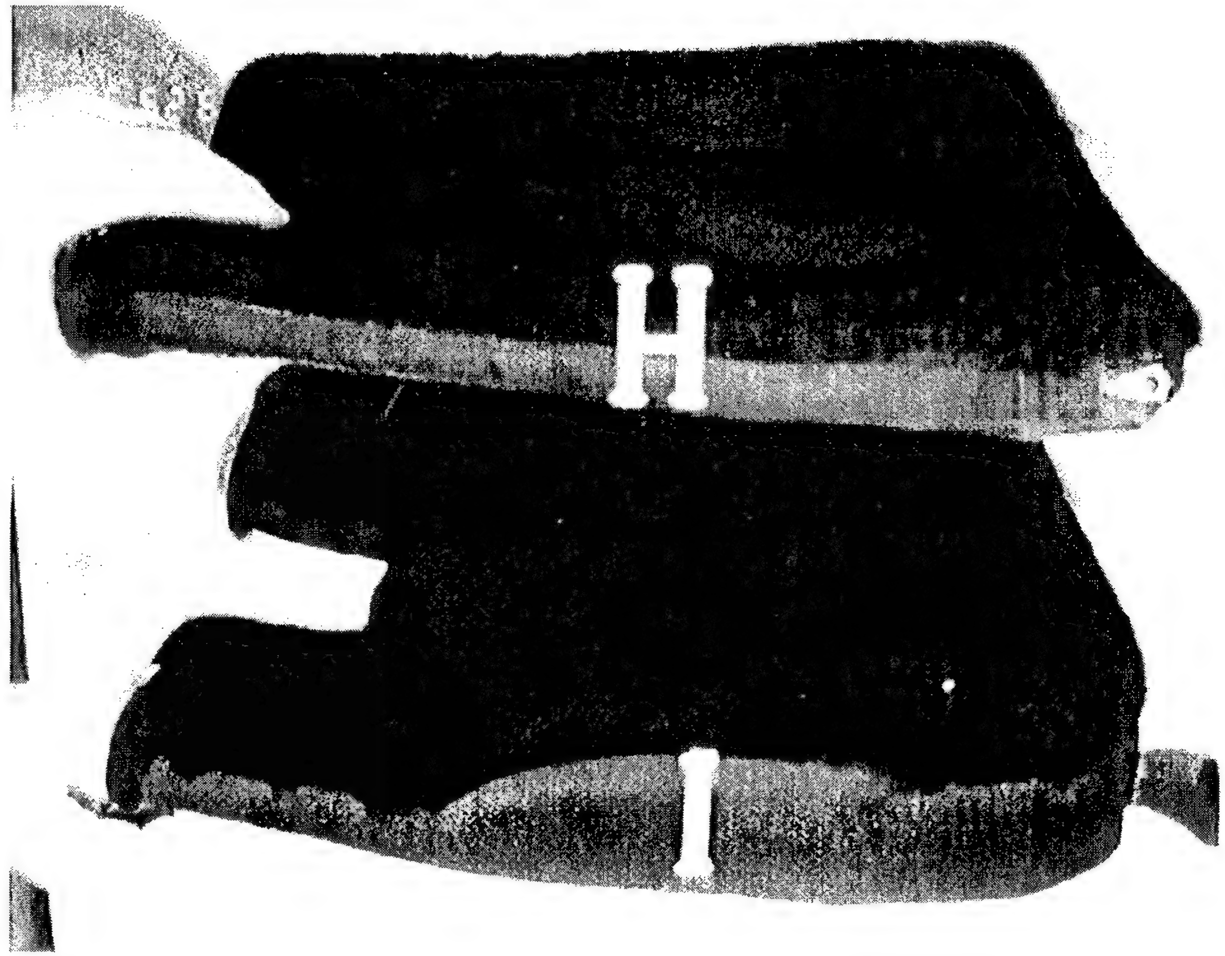
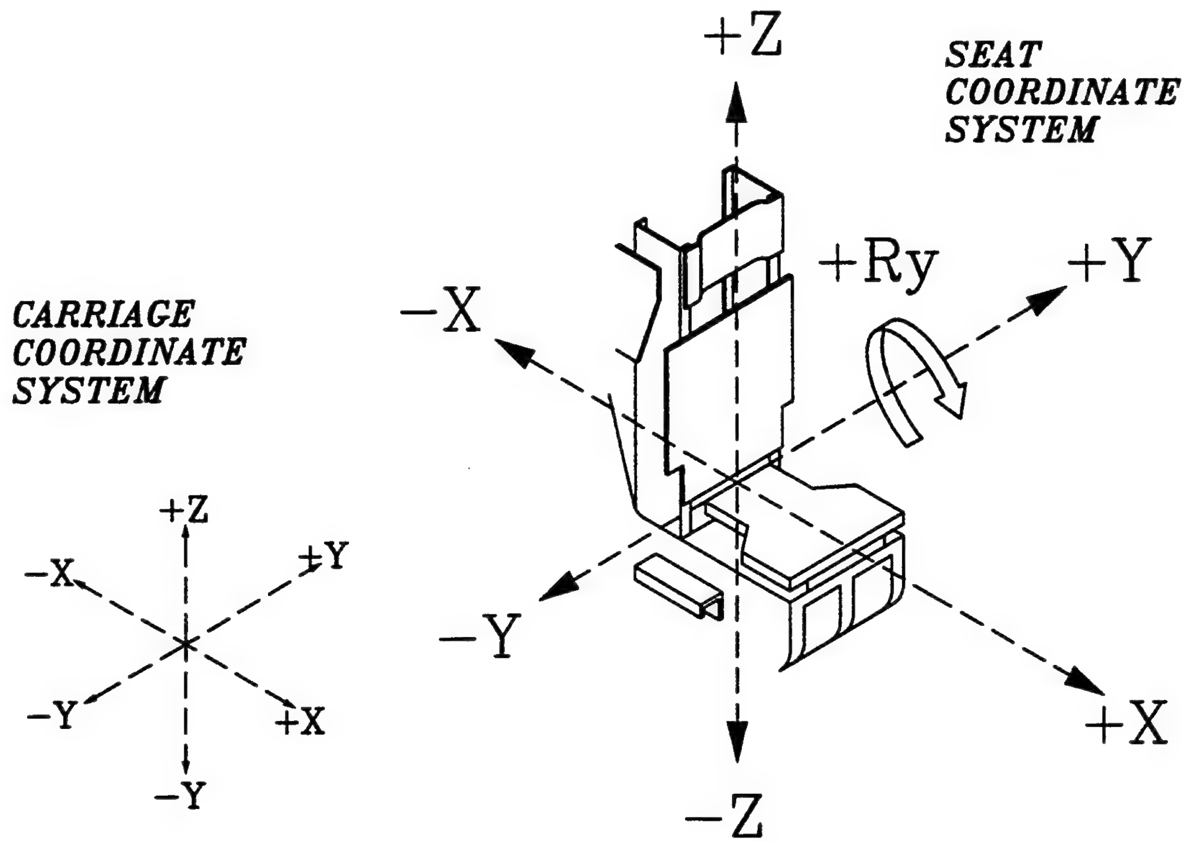


FIGURE A-4: CELL H (CURRENT B-2) AND CELL I (NEW B-2) SEAT CUSHIONS



1. ALL TRANSDUCERS EXCEPT THE CARRIAGE ACCELEROMETERS AND THE CARRIAGE VELOCITY TACHOMETER WERE REFERENCED TO THE SEAT COORDINATE SYSTEM. THE CARRIAGE TACHOMETER WAS WIRED TO PROVIDE A POSITIVE OUTPUT VOLTAGE DURING FREEFALL. THE CARRIAGE ACCELEROMETERS WERE REFERENCED TO THE CARRIAGE COORDINATE SYSTEM.

2. THE LINEAR ACCELEROMETERS WERE WIRED TO PROVIDE A POSITIVE OUTPUT VOLTAGE WHEN THE ACCELERATION EXPERIENCED BY THE ACCELEROMETER WAS APPLIED IN THE +x, +y OR +z DIRECTION AS SHOWN.

3. THE ANGULAR Ry ACCELEROMETERS WERE WIRED TO PROVIDE A POSITIVE OUTPUT VOLTAGE WHEN THE ANGULAR ACCELERATION EXPERIENCED BY THE ANGULAR ACCELEROMETER WAS APPLIED IN THE +y DIRECTION ACCORDING TO THE RIGHT HAND RULE AS SHOWN.

4. THE LOAD CELLS AND LOAD LINKS WERE WIRED TO PROVIDE A POSITIVE OUTPUT VOLTAGE WHEN THE FORCE EXERTED BY THE LOAD CELL ON THE SUBJECT WAS APPLIED IN THE +x, +y OR +z DIRECTION AS SHOWN.

FIGURE A-5: AL/CFBE COORDINATE SYSTEM

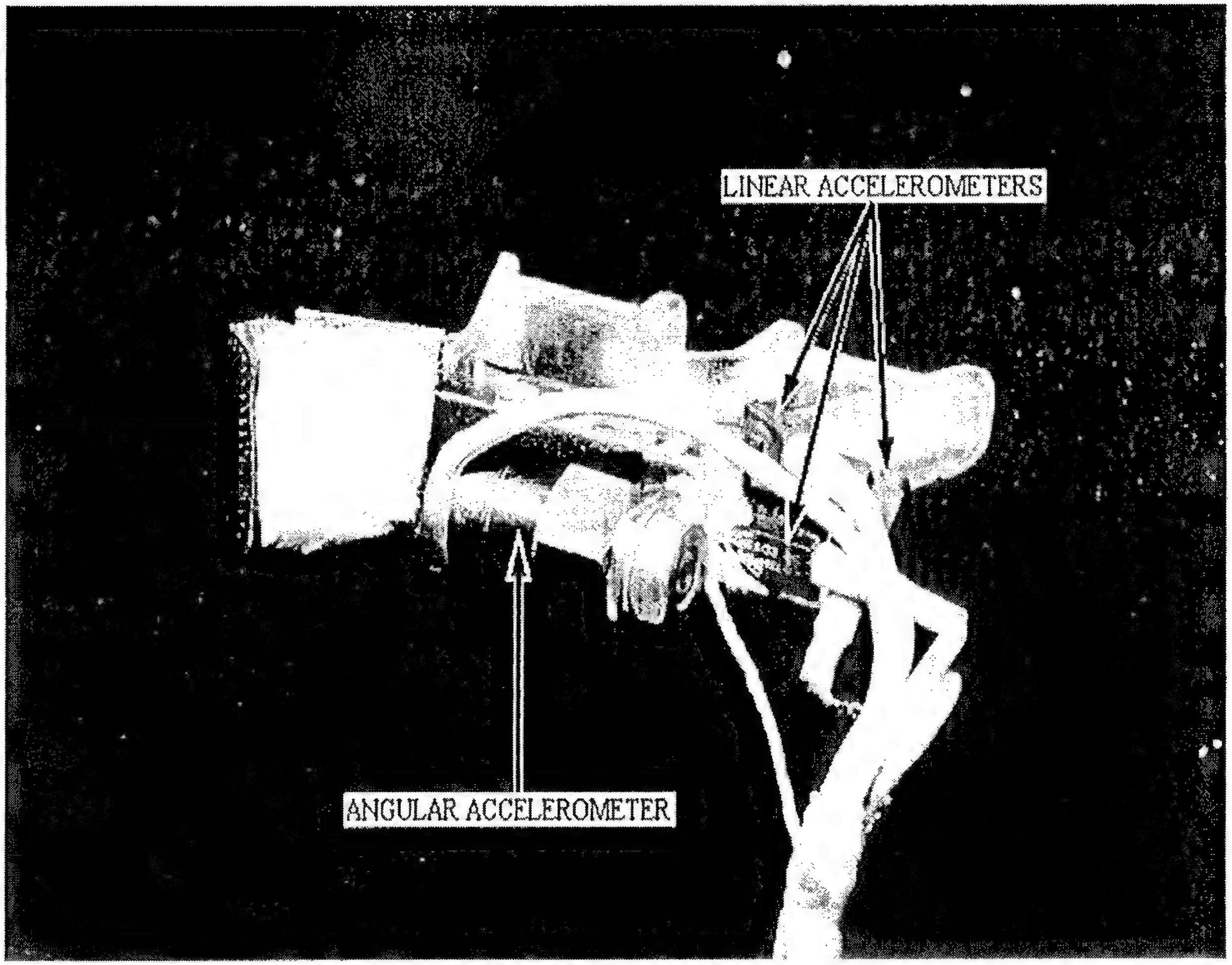


FIGURE A-6: HUMAN HEAD ACCELEROMETER PACKAGE

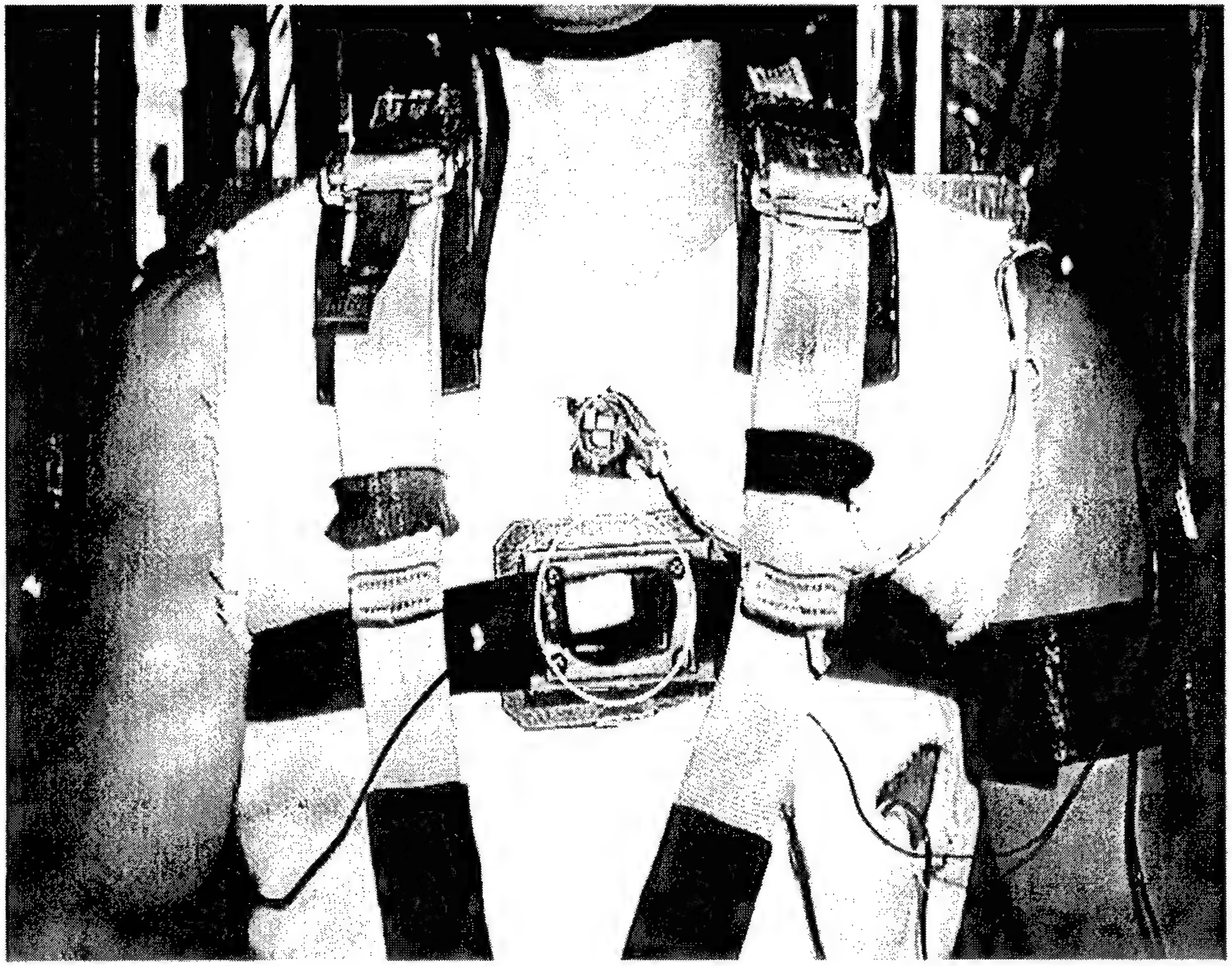


FIGURE A-7: CHEST ACCELEROMETER PACKAGE

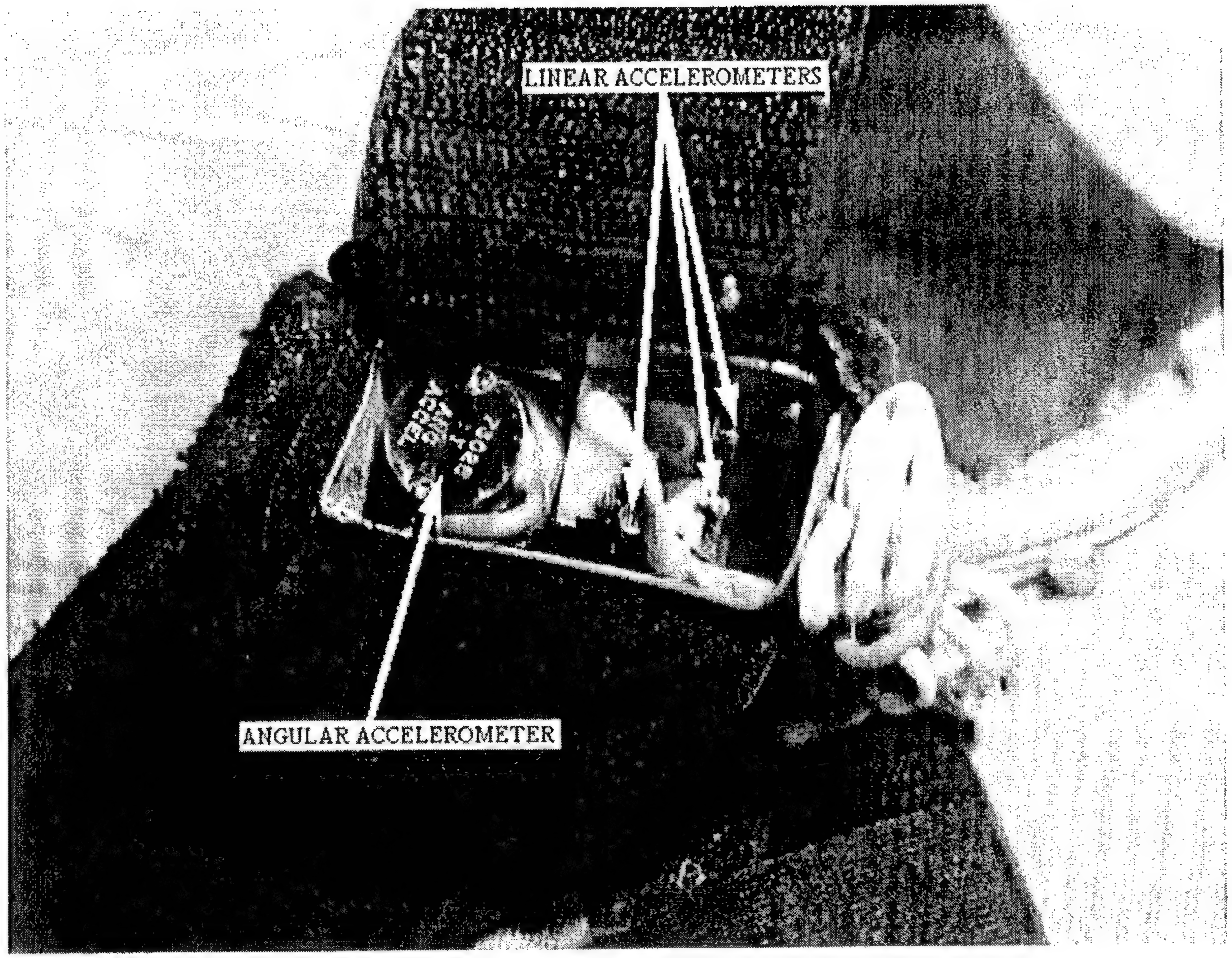


FIGURE A-8: CHEST ACCELEROMETER PACKAGE

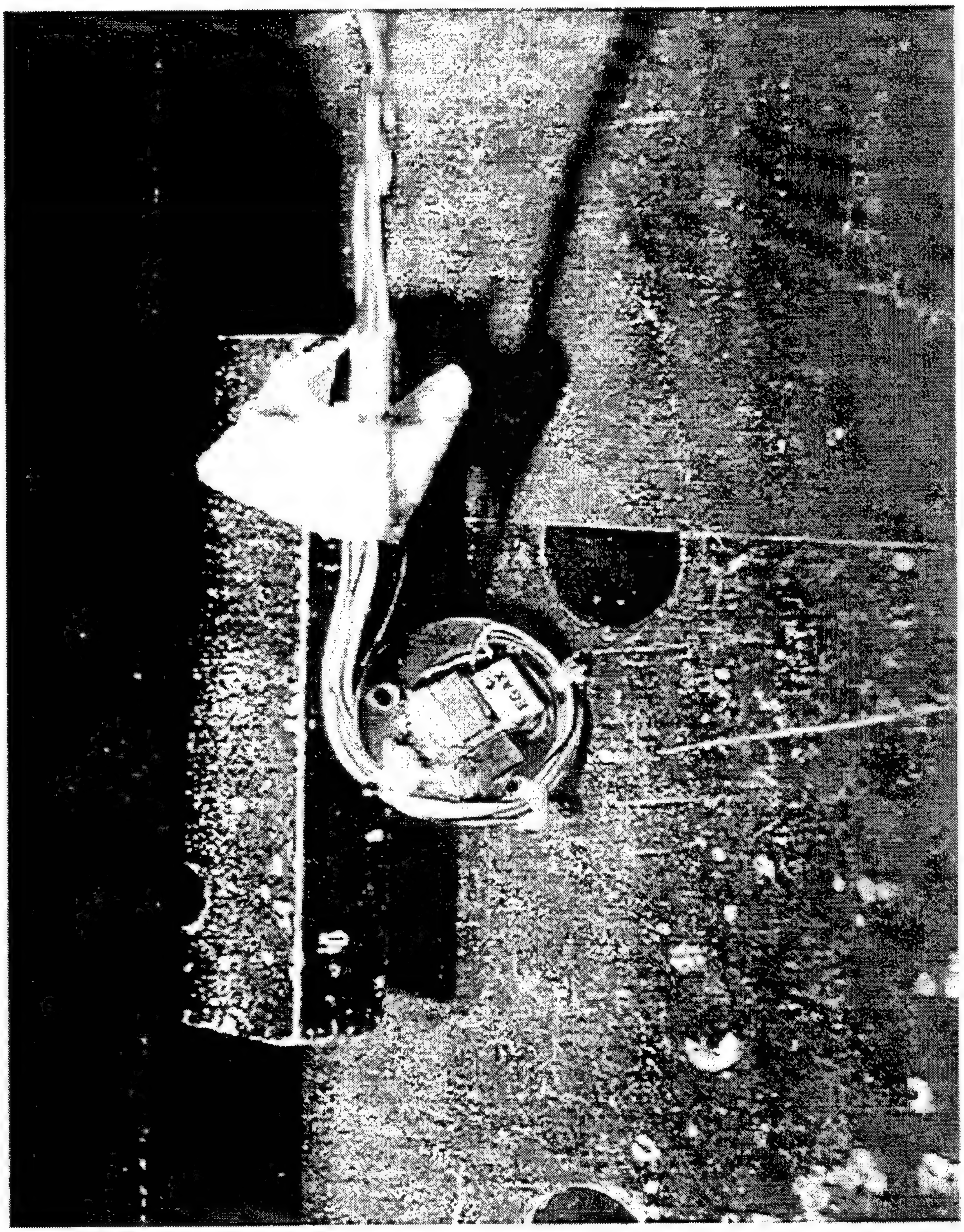


FIGURE A-9: T1 ACCELEROMETER PACKAGE

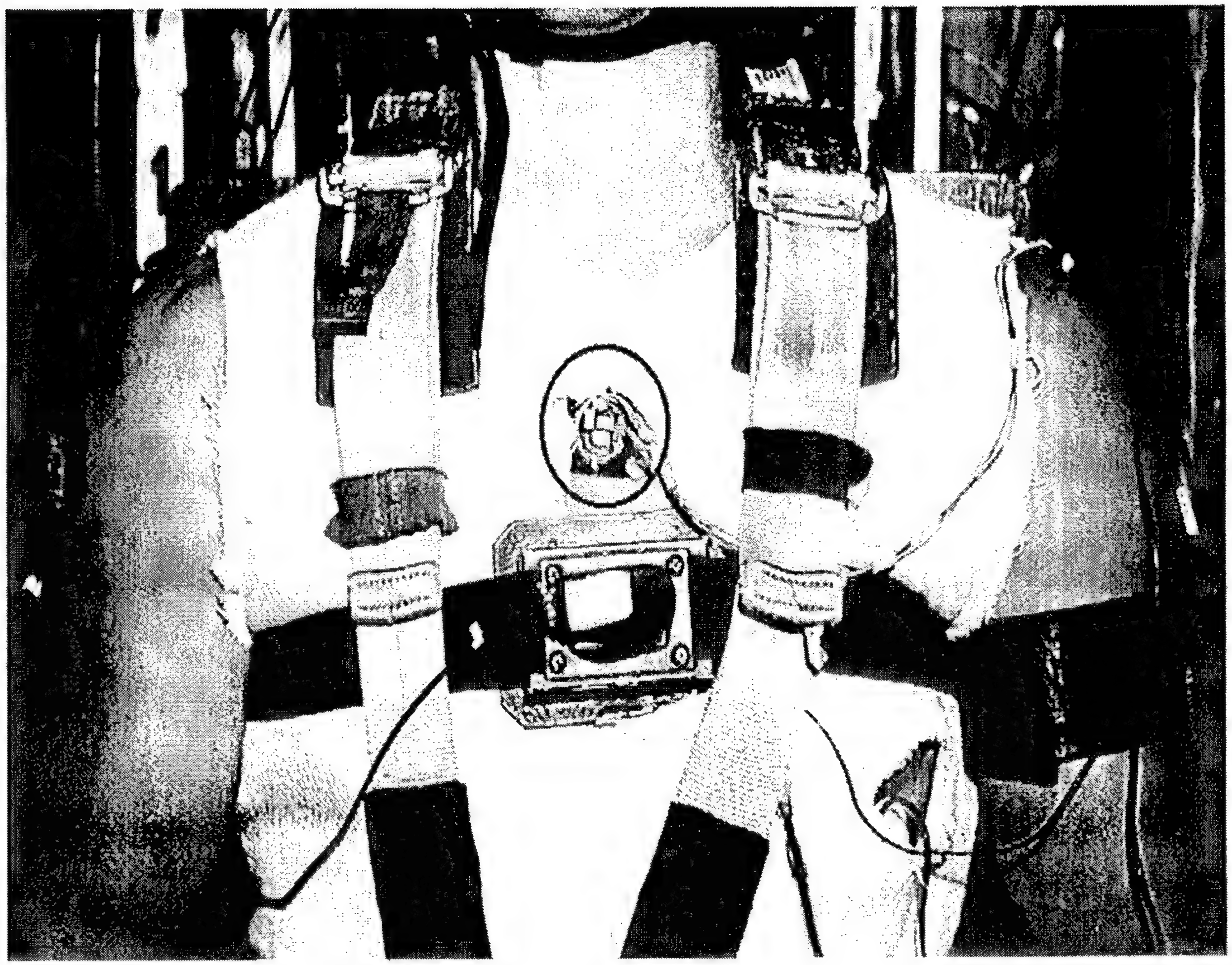
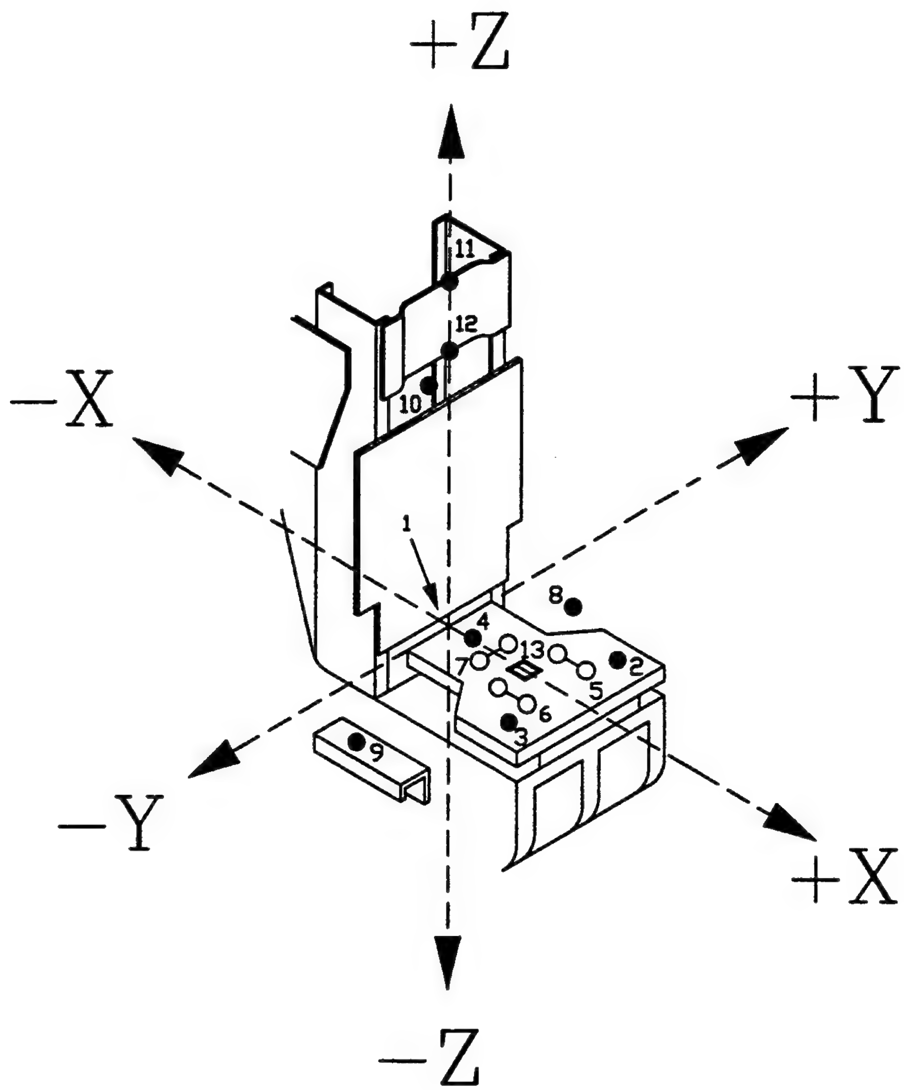


FIGURE A-10: T1 ACCELEROMETER PACKAGE MOUNTED ON SUBJECTS' UPPER CHEST



NO.	DESCRIPTION
1	SEAT REFERENCE POINT
2	LEFT SEAT Z FORCE
3	RIGHT SEAT Z FORCE
4	CENTER SEAT Z FORCE
5	LEFT SEAT X FORCE
6	RIGHT SEAT X FORCE
7	SEAT Y FORCE
8	LEFT LAP BELT FORCE
9	RIGHT LAP BELT FORCE
10	SHOULDER FORCE
11	UPPER HEADREST FORCE
12	LOWER HEADREST FORCE
13	SEAT X, Y & Z ACCELERATION

FIGURE A-11a TRANSDUCER LOCATIONS AND DIMENSIONS (PAGE 1 OF 3)

ALL DIMENSIONS ARE REFERENCED TO THE SEAT REFERENCE POINT (SRP). THE SEAT REFERENCE POINT IS LOCATED AT THE INTERSECTION OF THE SEAT PAN CENTER LINE AND THE SEAT BACK CENTER LINE (z AXIS).

CONTACT POINT DIMENSIONS IN INCHES (CM)

NO.	X	Y	Z
1	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2	17.90 (45.46)	5.00 (12.70)	- 1.38 (- 3.50)
3	17.90 (45.46)	- 5.00 (-12.70)	- 1.38 (- 3.50)
4	6.68 (16.96)	0.00 (0.00)	- 1.38 (- 3.50)
5	10.00 (25.41)	6.00 (15.25)	- 2.01 (- 5.10)
6	10.00 (25.41)	- 6.00 (-15.25)	- 2.01 (- 5.10)
7	9.26 (23.51)	1.99 (5.05)	- 2.01 (- 5.10)
8	0.81 (2.06)	9.00 (22.86)	- 1.77 (- 4.50)
9	0.81 (2.06)	- 9.00 (-22.86)	- 1.77 (- 4.50)
10	- 5.47 (-13.90)	0.00 (0.00)	27.24 (69.18)
11	- 0.87 (- 2.22)	0.00 (0.00)	37.25 (94.62)
12	- 0.87 (- 2.22)	0.00 (0.00)	32.35 (82.17)
13	12.33 (31.31)	0.00 (0.00)	- 1.85 (- 4.70)

(SEE FIGURE A-11a FOR DESCRIPTIONS OF TRANSDUCER ITEM NUMBERS)

THE SEAT ACCELEROMETER MEASUREMENTS (ITEM 13) ARE TAKEN AT THE CENTER OF THE ACCELEROMETER BLOCK.

THE CONTACT POINT IS THE POINT ON THE LOAD CELL AT WHICH THE EXTERNAL FORCE IS APPLIED.

THE MEASUREMENTS FOR THE LOAD CELLS WHICH ANCHOR THE HARNESS (ITEMS 8, 9 & 10) ARE TAKEN AT THE POINT WHERE THE HARNESS IS ATTACHED TO THE LOAD CELL.

THE ABOVE MEASUREMENTS ARE VALID FOR TESTS 3465 THROUGH 3570 (PRIOR TO RELOCATING THE SEAT BACK AND HEADREST). THE DIMENSIONS DO NOT ACCOUNT FOR THE EFFECT OF THE BOOSTER SEAT (WHEN USED).

FIGURE A-11b: TRANSDUCER LOCATIONS AND DIMENSIONS (PAGE 2 OF 3)

ALL DIMENSIONS ARE REFERENCED TO THE SEAT REFERENCE POINT (SRP). THE SEAT REFERENCE POINT IS LOCATED AT THE INTERSECTION OF THE SEAT PAN CENTER LINE AND THE SEAT BACK CENTER LINE (z AXIS).

CONTACT POINT DIMENSIONS IN INCHES (CM)

NO.	X	Y	Z
1	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2	16.90 (42.93)	5.00 (12.70)	- 1.38 (- 3.50)
3	16.90 (42.93)	- 5.00 (-12.70)	- 1.38 (- 3.50)
4	5.68 (14.43)	0.00 (0.00)	- 1.38 (- 3.50)
5	9.00 (22.86)	6.00 (15.25)	- 2.01 (- 5.10)
6	9.00 (22.86)	- 6.00 (-15.25)	- 2.01 (- 5.10)
7	8.26 (20.98)	1.99 (5.05)	- 2.01 (- 5.10)
8	- 0.19 (- 0.48)	9.00 (22.86)	- 1.77 (- 4.50)
9	- 0.19 (- 0.48)	- 9.00 (-22.86)	- 1.77 (- 4.50)
10	- 6.47 (-16.43)	0.00 (0.00)	27.24 (69.18)
11	0.11 (0.29)	0.00 (0.00)	36.25 (92.08)
12	0.11 (0.29)	0.00 (0.00)	31.35 (79.63)
13	11.33 (28.78)	0.00 (0.00)	- 1.85 (- 4.70)

(SEE FIGURE A-11a FOR DESCRIPTIONS OF TRANSDUCER ITEM NUMBERS)

THE SEAT ACCELEROMETER MEASUREMENTS (ITEM 13) ARE TAKEN AT THE CENTER OF THE ACCELEROMETER BLOCK.

THE CONTACT POINT IS THE POINT ON THE LOAD CELL AT WHICH THE EXTERNAL FORCE IS APPLIED.

THE MEASUREMENTS FOR THE LOAD CELLS WHICH ANCHOR THE HARNESS (ITEMS 8, 9 & 10) ARE TAKEN AT THE POINT WHERE THE HARNESS IS ATTACHED TO THE LOAD CELL.

THE ABOVE MEASUREMENTS ARE VALID FOR TESTS 3571 THROUGH 3829 (AFTER RELOCATING THE SEAT BACK AND HEADREST). THE DIMENSIONS DO NOT ACCOUNT FOR THE EFFECT OF THE BOOSTER SEAT (WHEN USED).

FIGURE A-11c: TRANSDUCER LOCATIONS AND DIMENSIONS (PAGE 3 OF 3)

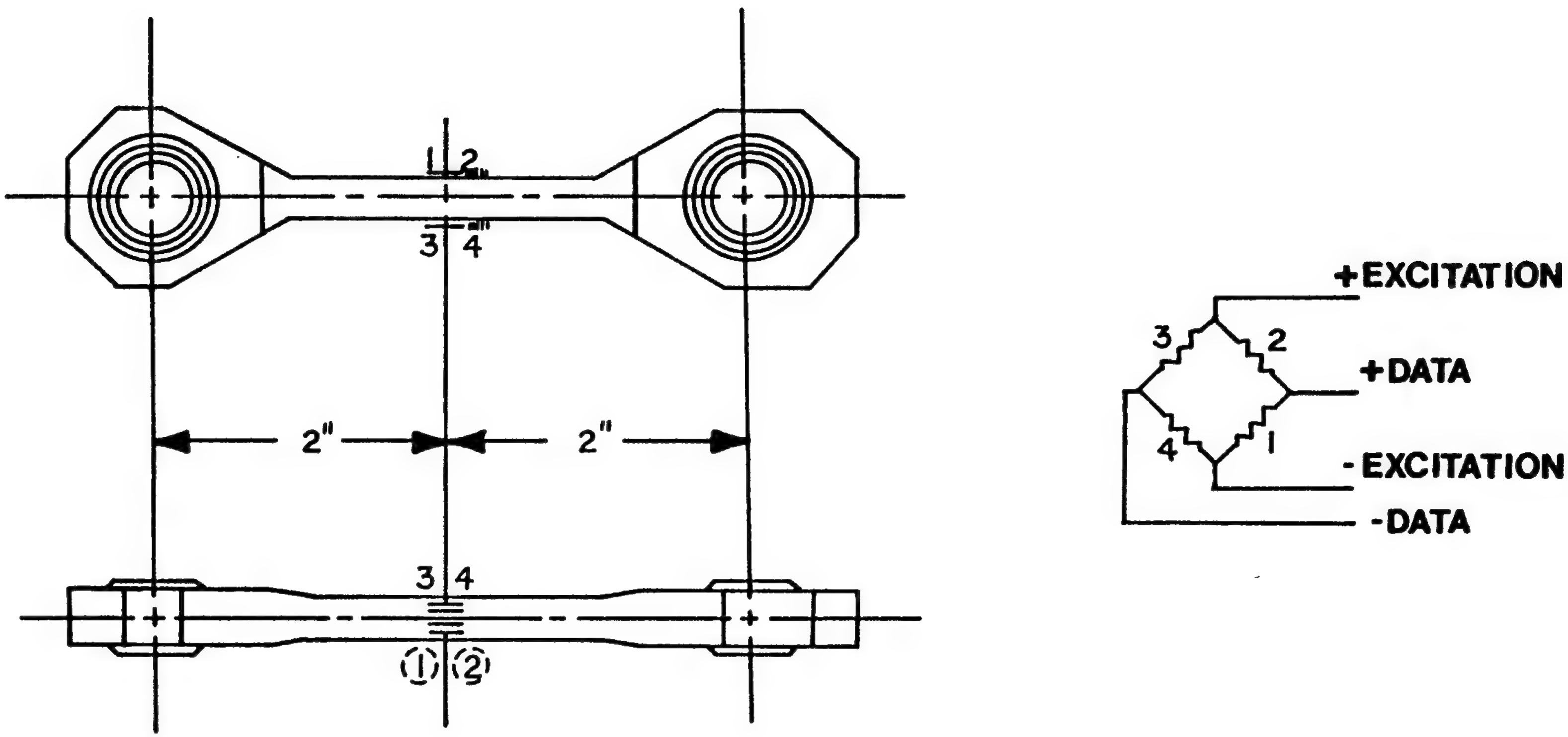
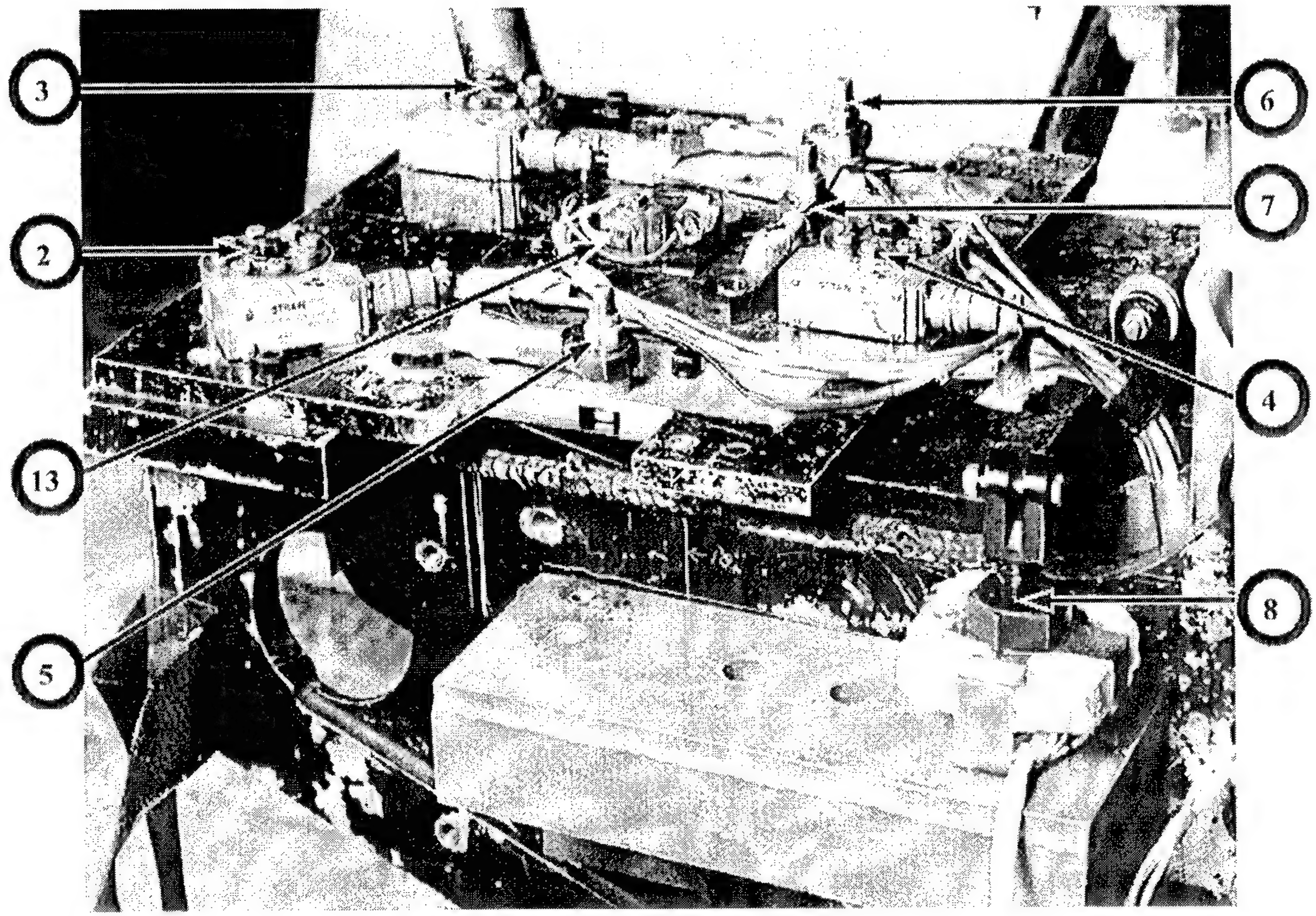


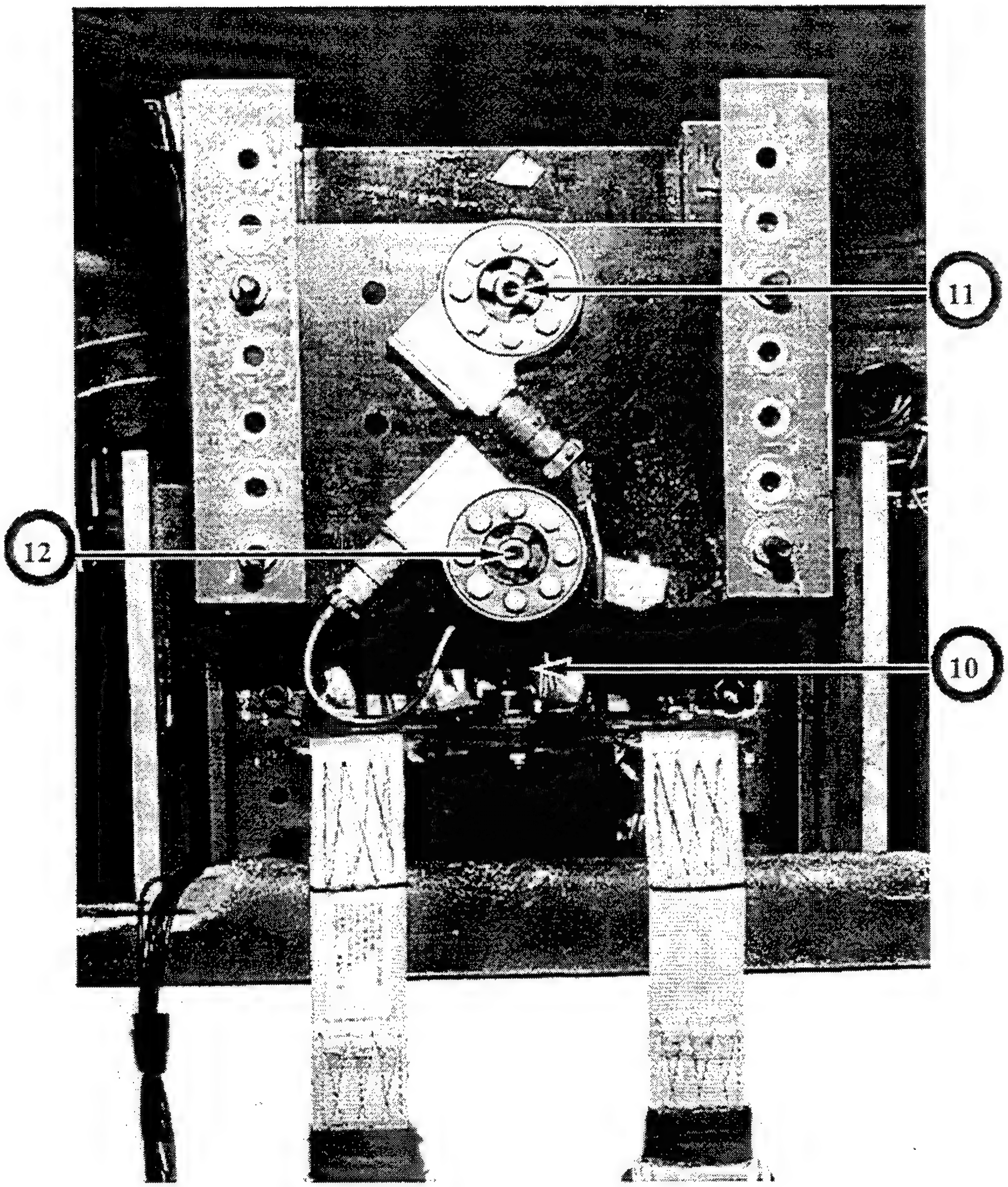
FIGURE A-12: LOAD LINK INSTRUMENTATION



NOTE: REFER TO FIGURE A-11a FOR A DESCRIPTION OF THE TRANSDUCER ITEM NUMBERS.

ITEM 9 NOT SHOWN

FIGURE A-13: SEAT PAN INSTRUMENTATION



NOTE: REFER TO FIGURE A-11a FOR A DESCRIPTION OF THE TRANSDUCER ITEM NUMBERS.

FIGURE A-14: HEADREST AND SHOULDER LOAD CELL INSTRUMENTATION

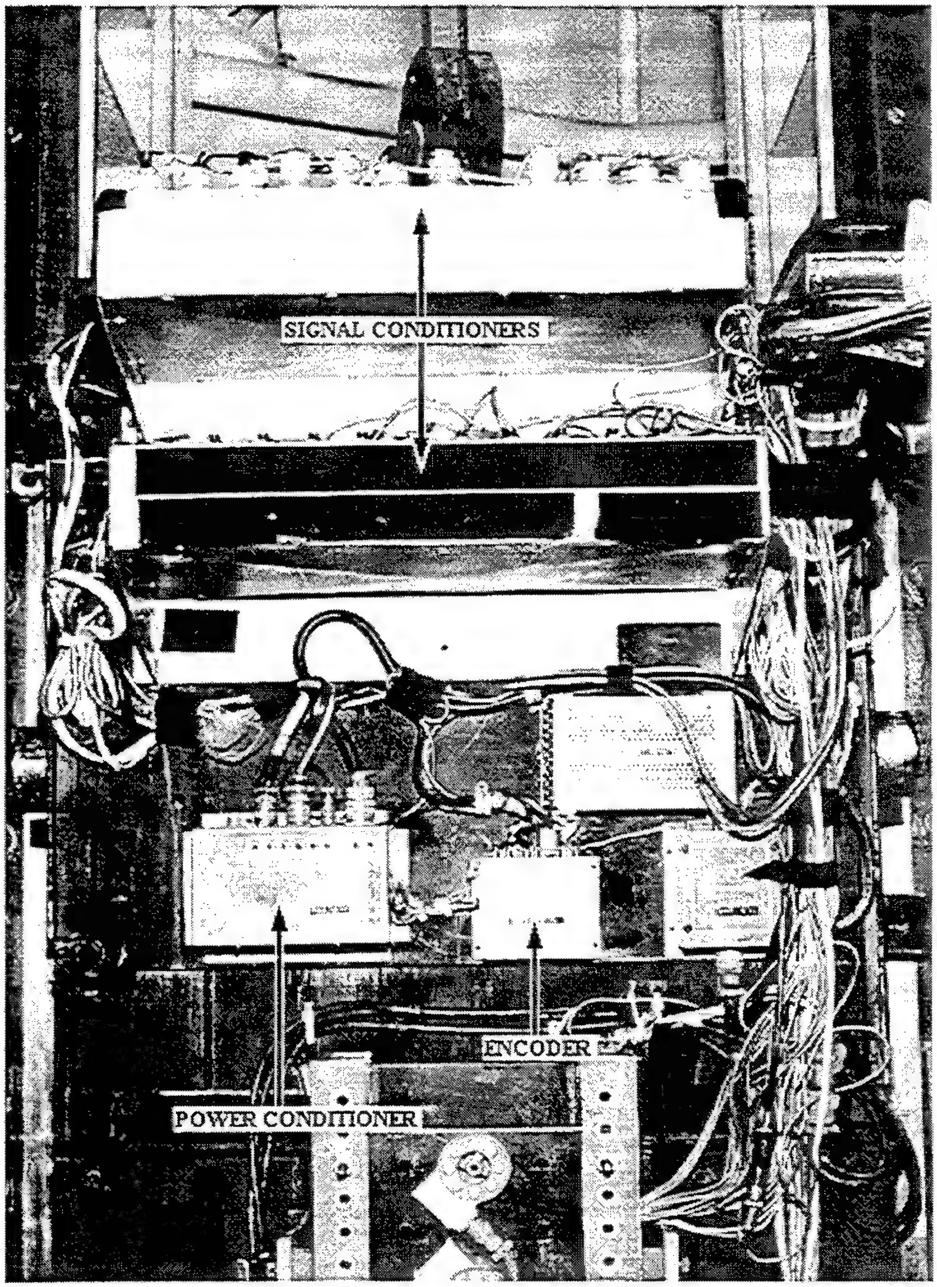


FIGURE A-15: ADACS INSTALLATION

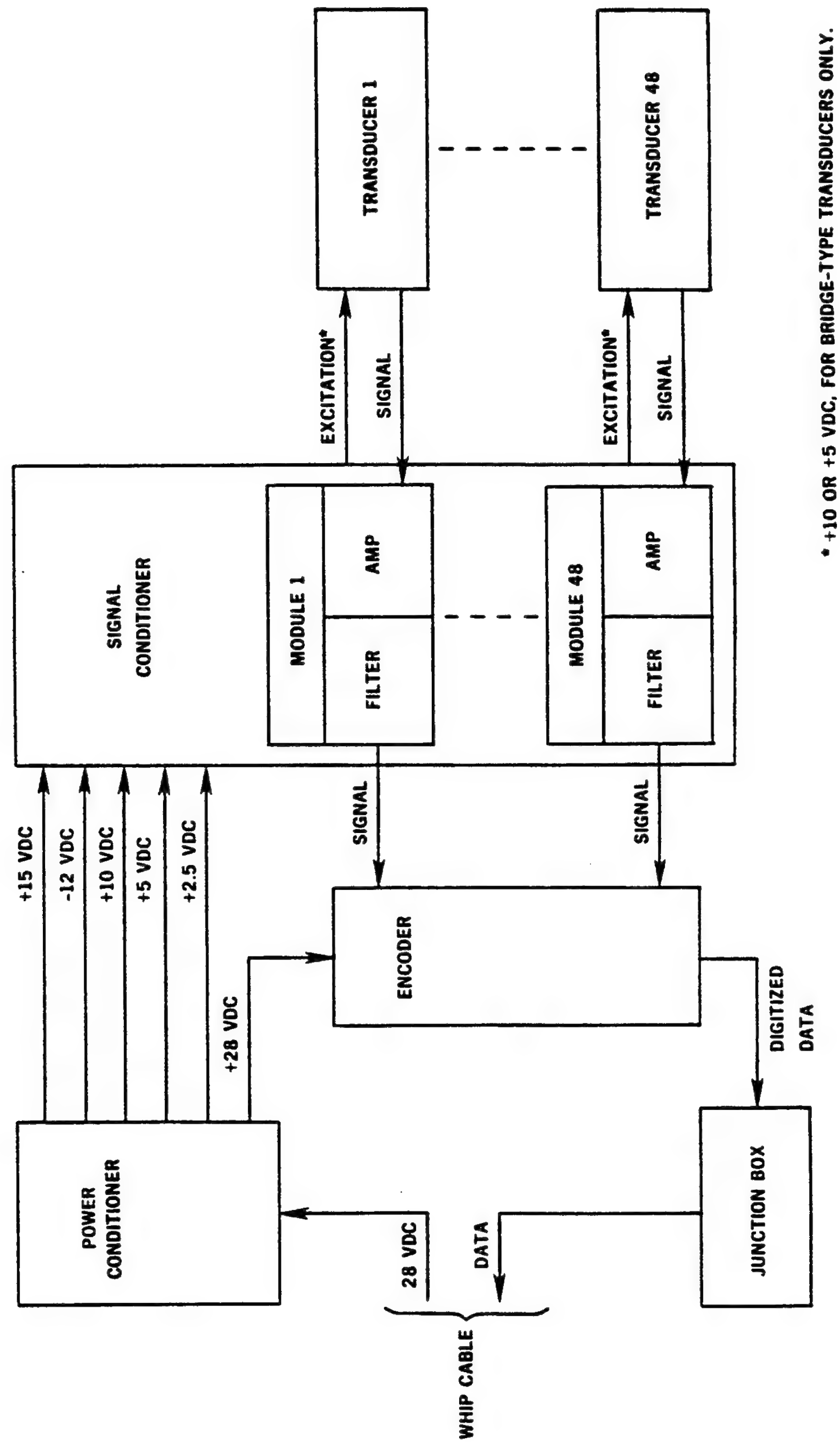


FIGURE A-16: AUTOMATIC DATA ACQUISITION AND CONTROL SYSTEM

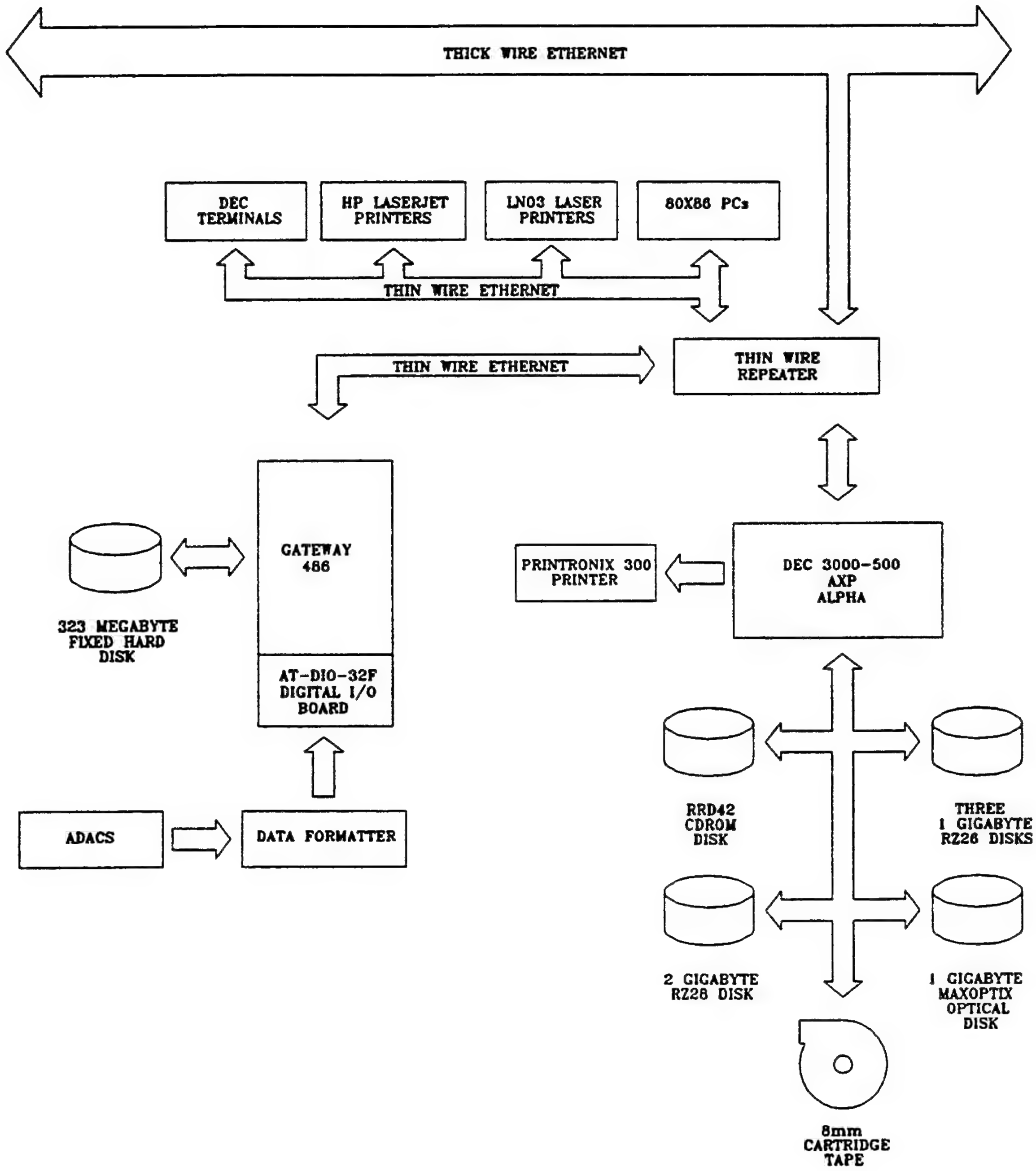


FIGURE A-17: DATA ACQUISITION AND STORAGE SYSTEM BLOCK DIAGRAM

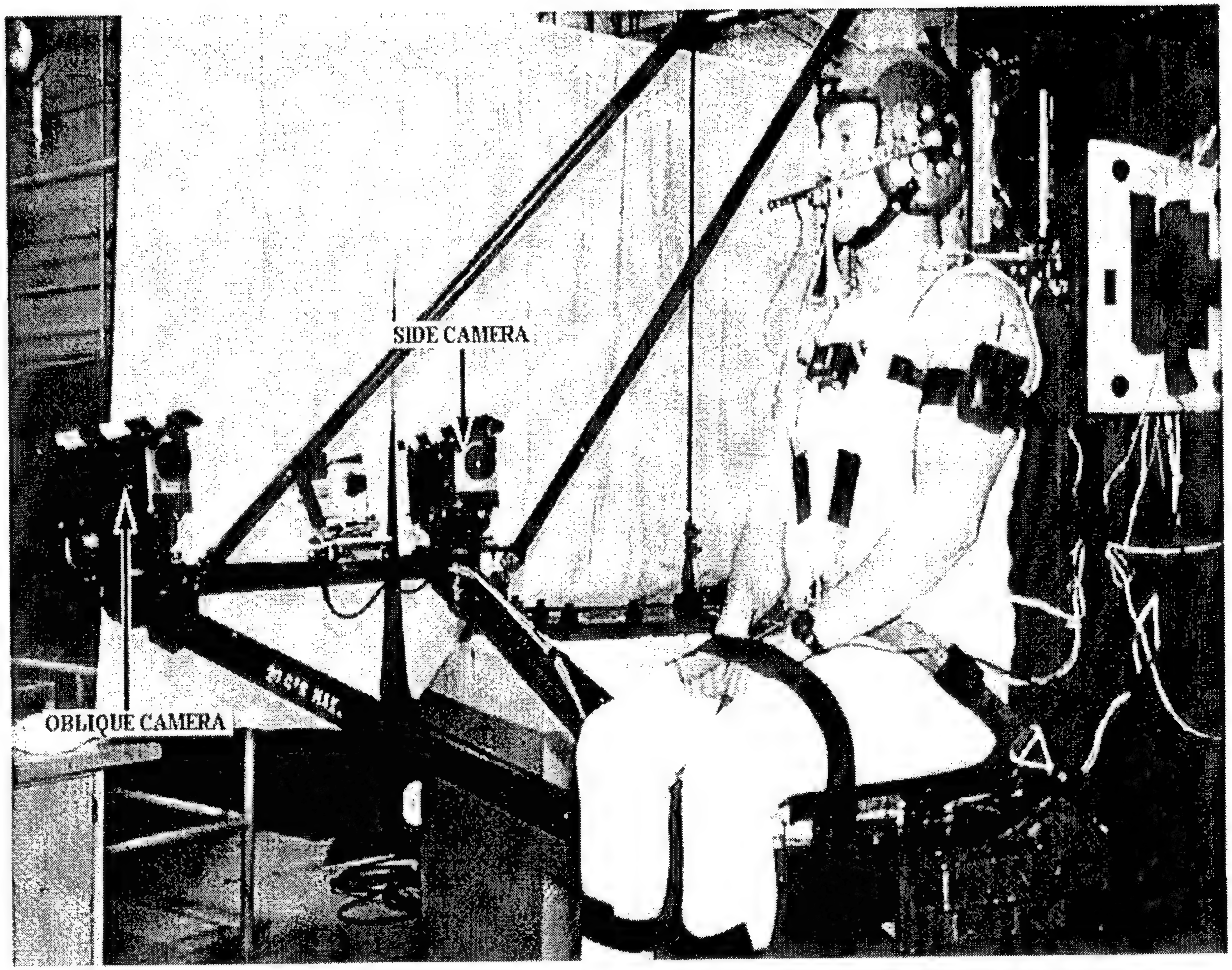


FIGURE A-18: ONBOARD SELSPOT CAMERA LOCATIONS

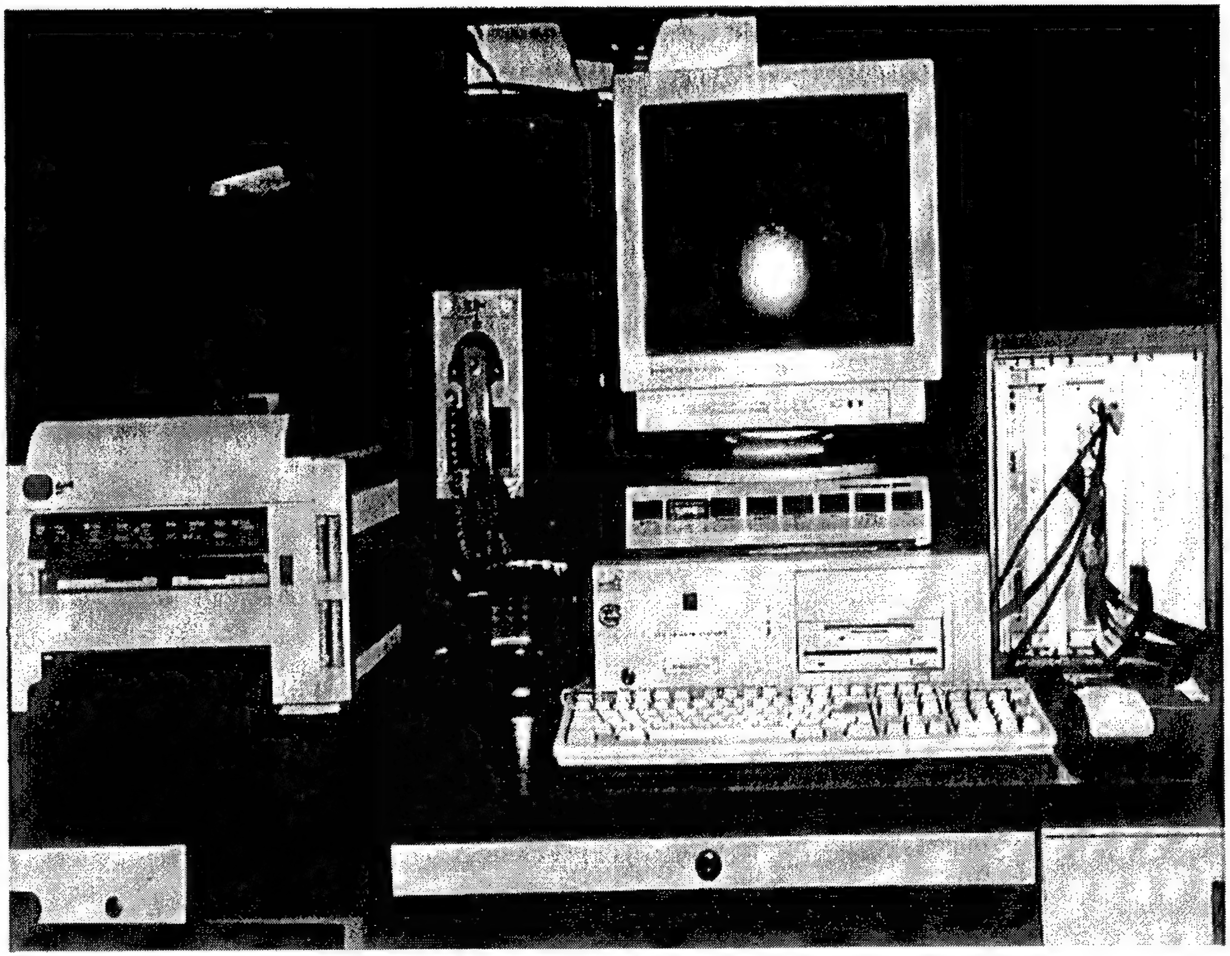


FIGURE A-19: SELSPOT COMPUTER SYSTEM

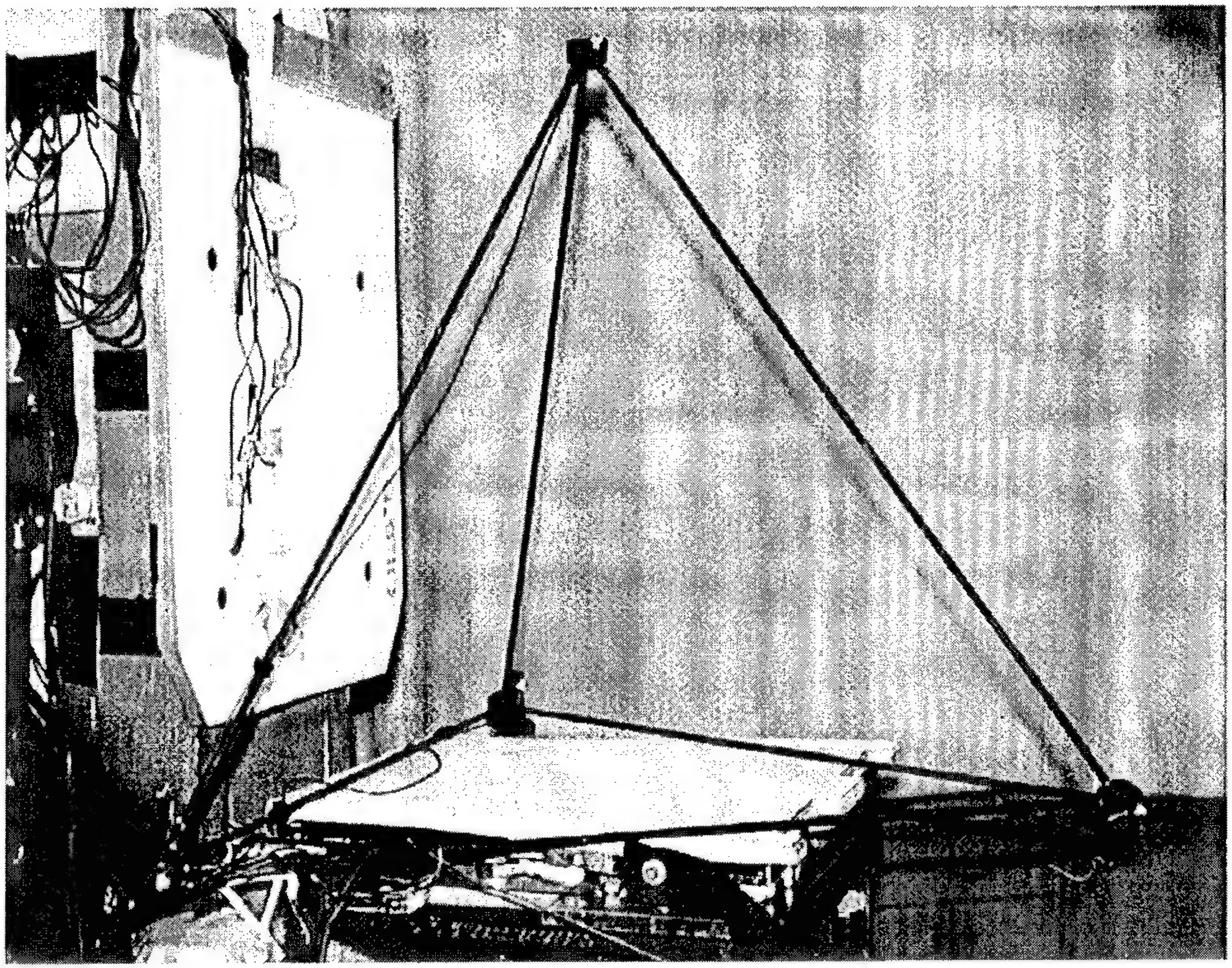
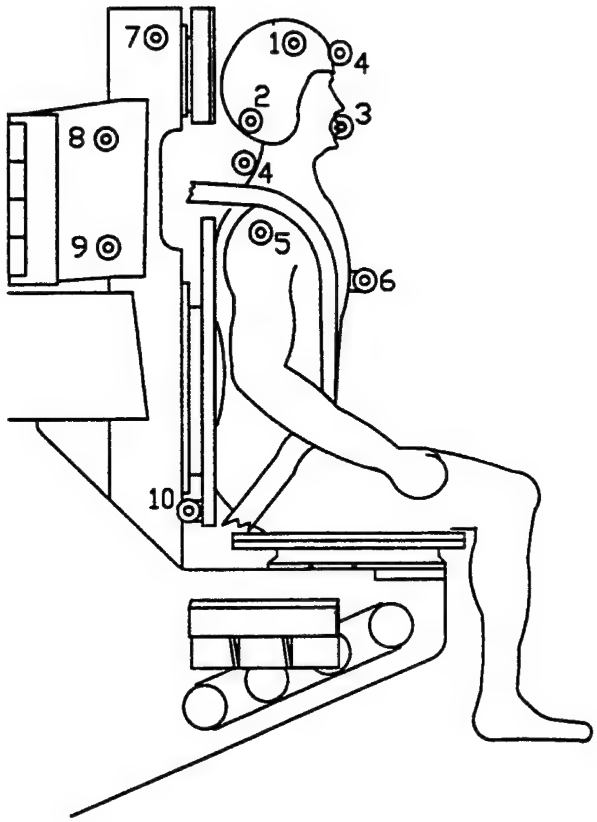


FIGURE A-20: POSITION REFERENCE STRUCTURE (PRS)

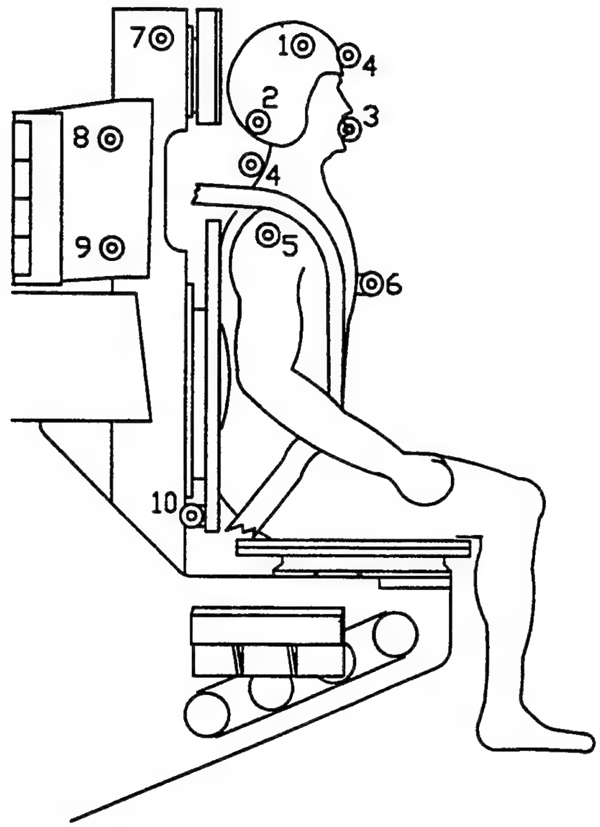


ALL DIMENSIONS ARE REFERENCED TO THE SEAT REFERENCE POINT (SRP). THE SEAT REFERENCE POINT IS LOCATED AT THE INTERSECTION OF THE SEAT PAN CENTER LINE AND THE SEAT BACK CENTER LINE (z AXIS).

	DESCRIPTION	DIMENSIONS IN MILLIMETERS		
		x	y	z
1.	HELMET TOP	-	-	-
2.	HELMET BOTTOM	-	-	-
3.	BITE BAR	-	-	-
4.	NECK/HELMET BROW[1]	-	-	-
5.	SHOULDER	-	-	-
6.	CHEST	-	-	-
7.	HEAD REST[2]	- 35.40	-171.70	+1026.70
8.	UPPER NUMBER FRAME[2]	-236.00	-241.40	+ 844.40
9.	LOWER NUMBER FRAME[2]	-239.20	-242.60	+ 571.40
10.	STATIONARY SEAT BACK[2]	- 49.50	-238.10	+ 142.40

NOTES: [1] NECK LED USED FOR CELLS A, B, C, C1, H & I
HELMET BROW USED FOR CELLS D, E, F, G & J
[2] DIMENSIONS FOR LEDs 7 THROUGH 10 ARE VALID FOR TESTS 3465 THROUGH 3570

FIGURE A-21: INFRARED TARGET (LED) LOCATIONS



ALL DIMENSIONS ARE REFERENCED TO THE SEAT REFERENCE POINT (SRP). THE SEAT REFERENCE POINT IS LOCATED AT THE INTERSECTION OF THE SEAT PAN CENTER LINE AND THE SEAT BACK CENTER LINE (z AXIS).

	DESCRIPTION	DIMENSIONS IN MILLIMETERS x	y	z
1.	HELMET TOP	-	-	-
2.	HELMET BOTTOM	-	-	-
3.	BITE BAR	-	-	-
4.	NECK/HELMET BROW[1]	-	-	-
5.	SHOULDER	-	-	-
6.	CHEST	-	-	-
7.	HEAD REST[2]	- 60.80	-171.70	+1026.70
8.	UPPER NUMBER FRAME[2]	-261.40	-241.40	+ 844.40
9.	LOWER NUMBER FRAME[2]	-264.60	-242.60	+ 571.40
10.	STATIONARY SEAT BACK[2]	- 71.90	-238.10	+ 142.40

NOTES: [1] NECK LED USED FOR CELLS A, B, C, C1, H & I
HELMET BROW USED FOR CELLS D, E, F, G & J
[2] DIMENSIONS FOR LEDs 7 THROUGH 10 ARE VALID FOR TESTS 3571 THROUGH 3829

FIGURE A-22: INFRARED TARGET (LED) LOCATIONS

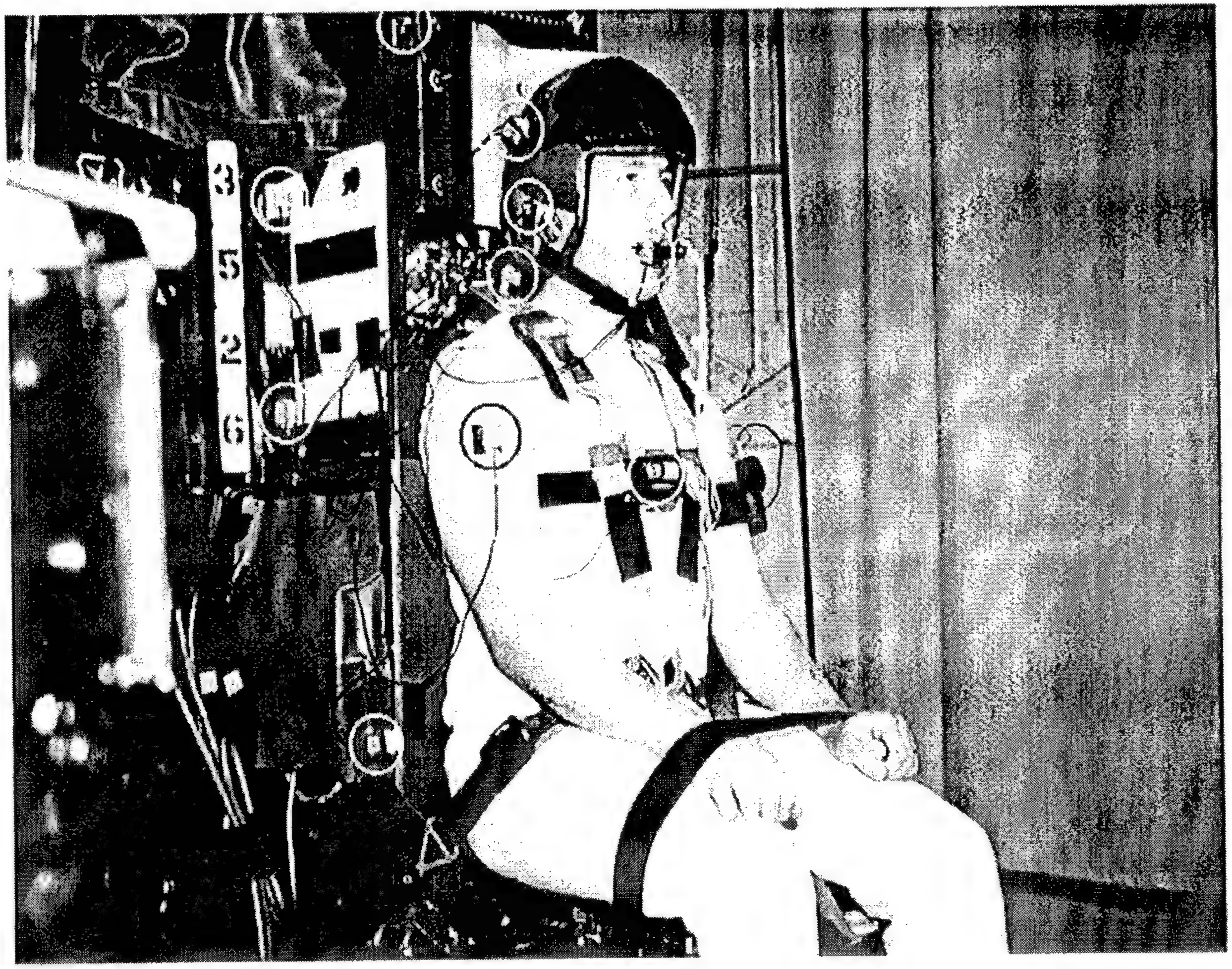


FIGURE A-23: INFRARED TARGETS (CELLS A,B,C,C1,H & I)

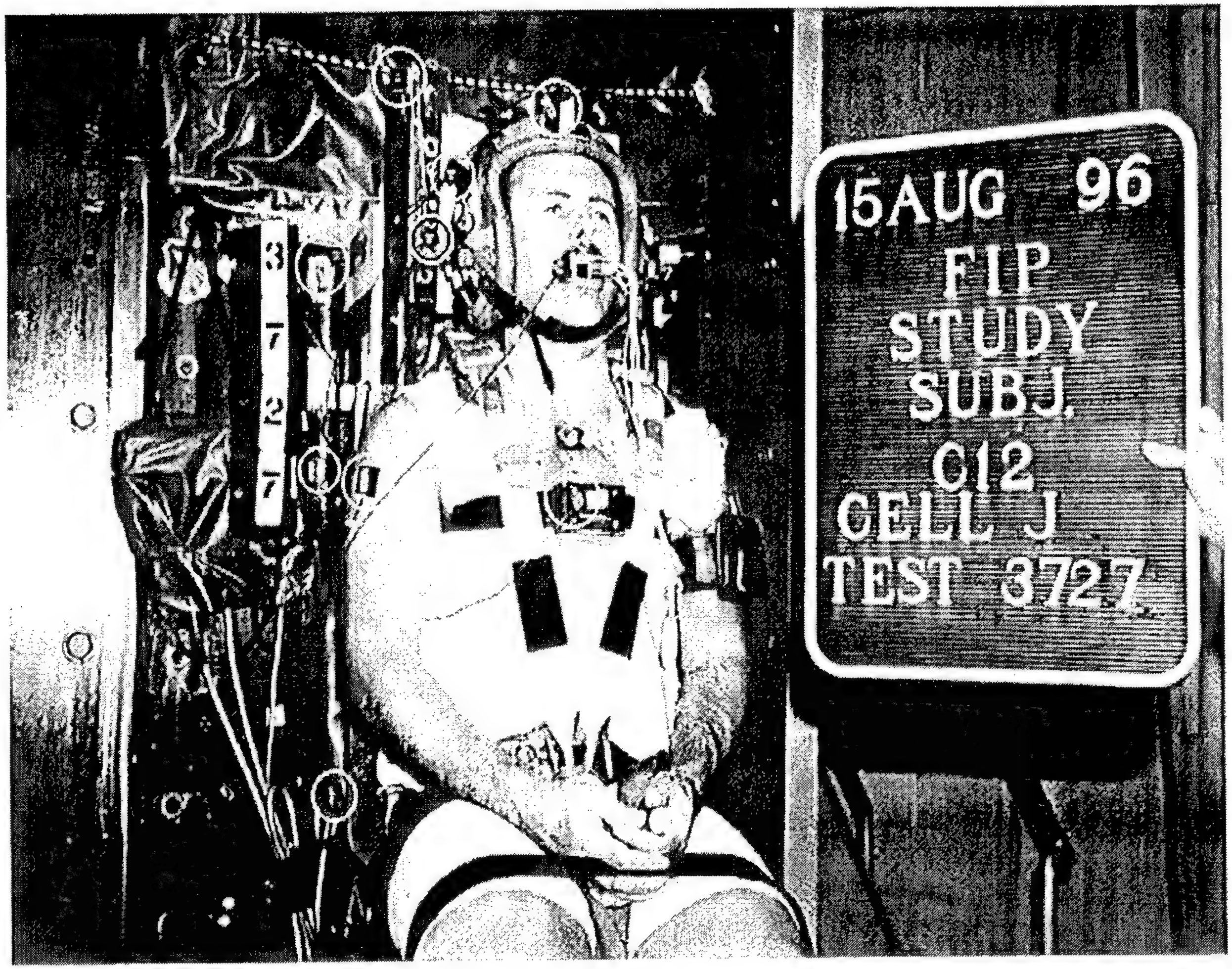


FIGURE A-24: INFRARED TARGETS (CELLS D,E,F,G & J)

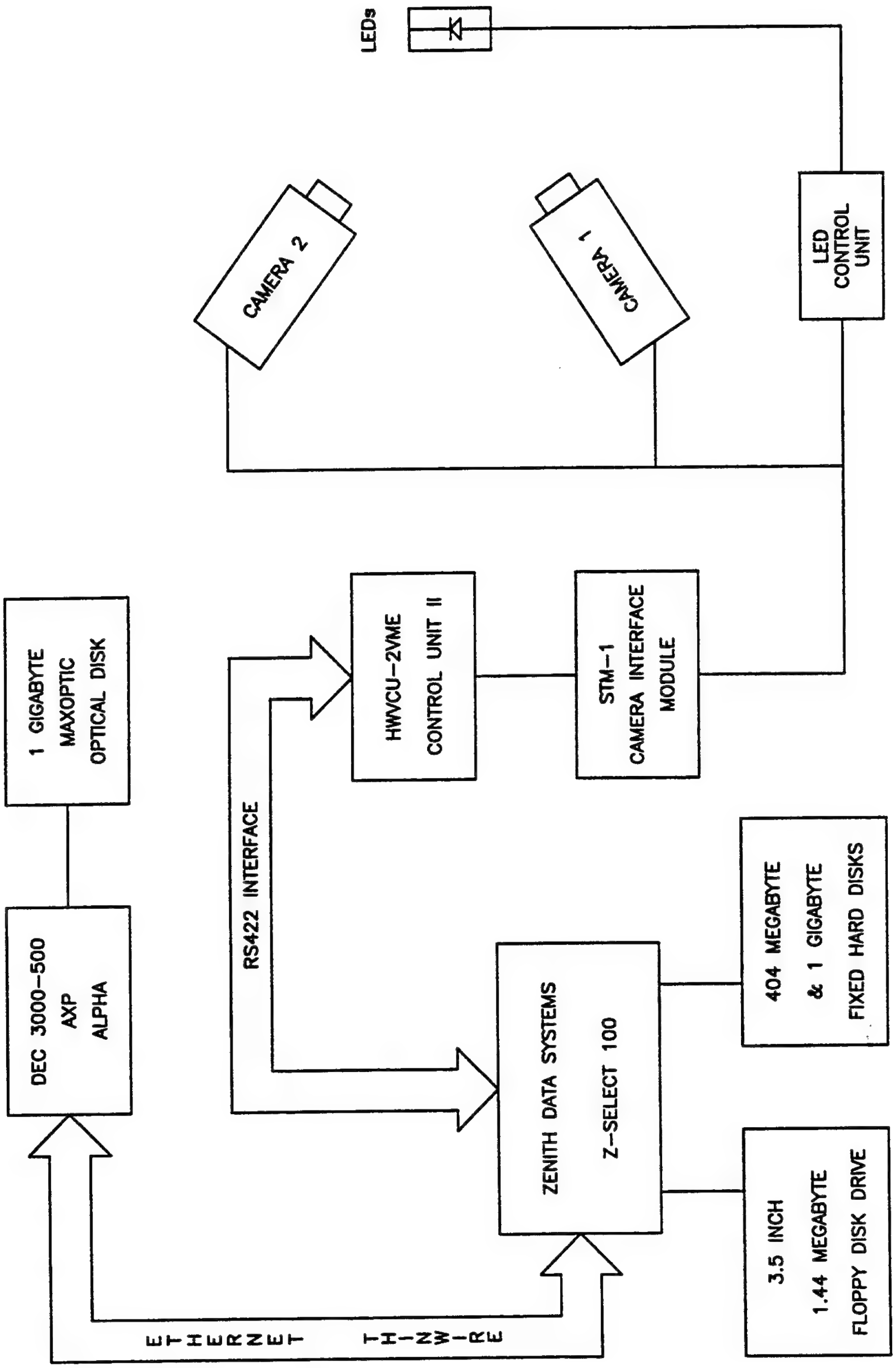


FIGURE A-25: SELSPOT MOTION ANALYSIS SYSTEM

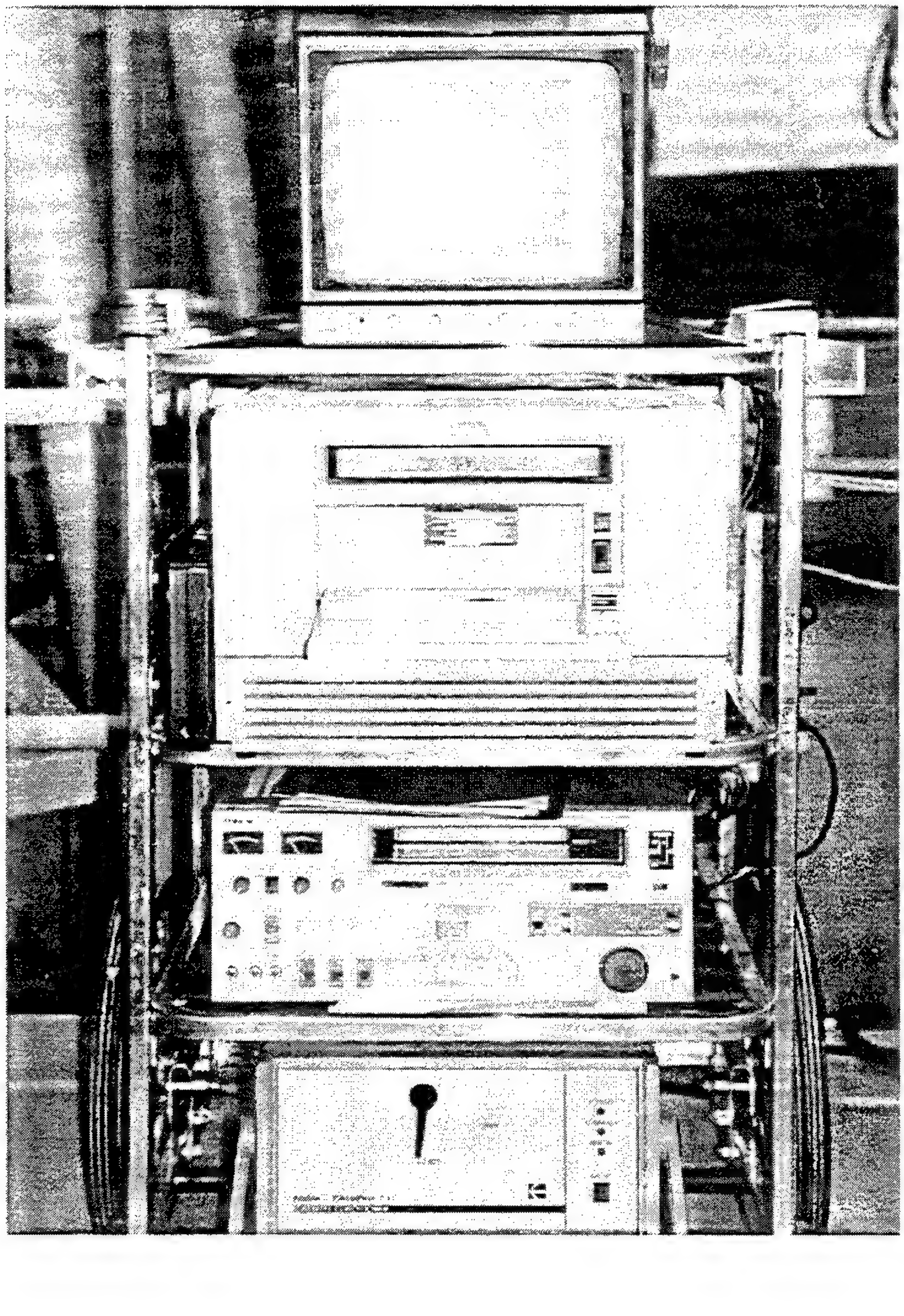


FIGURE A-26: KODAK EKTAPRO 1000 VIDEO SYSTEM

APPENDIX B

Sample Test Data

FIP STUDY TEST: 3533 TEST DATE: 15-MAY-1996 SUBJ: B-17 WT: 138.0
NOM G: 10.0 CELL: C

DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK TIME (MS)				-120.	
IMPACT RISE TIME (MS)				75.1	
IMPACT DURATION (MS)				147.9	
CARRIAGE Z ACCELERATION (G)	0.04	9.85	0.46	72.	0.
CARRIAGE VELOCITY (FPS)	26.73	27.51	1.20	11.	394.
SEAT ACCELERATION (G)					
X AXIS	-0.02	1.48	-1.04	18.	9.
Y AXIS	-0.01	1.03	-2.01	38.	52.
Z AXIS	-0.01	10.21	-0.25	74.	9.
Z AXIS DRI	0.00	12.82	-1.71	97.	167.
HEAD ACCELERATION (G)					
X AXIS	0.03	2.92	-1.48	84.	116.
Y AXIS	-0.05	1.48	-1.43	95.	150.
Z AXIS	-0.10	15.01	-0.37	84.	166.
RESULTANT	0.18	15.33	0.09	84.	9.
RY (RAD/SEC2)	8.17	239.64	-245.21	115.	84.
CHEST ACCELERATION (G)					
X AXIS	0.00	5.63	-0.76	84.	125.
Y AXIS	0.14	0.99	-0.52	73.	141.
Z AXIS	0.00	13.64	-0.11	84.	11.
RESULTANT	0.15	14.76	0.14	84.	13.
RY (RAD/SEC2)	5.31	330.87	-214.84	60.	37.
T1 ACCELERATION (G)					
X AXIS	0.06	1.37	-5.09	65.	108.
Y AXIS	0.02	0.21	-1.62	220.	66.
Z AXIS	0.12	12.93	-0.25	65.	0.
RESULTANT	0.24	13.11	0.19	65.	15.
HEADREST X FORCES (LB)					
LOWER	25.05	47.52	-1.26	148.	325.
UPPER	-5.06	-2.86	-11.76	415.	37.
SUM	19.99	43.20	-5.37	148.	259.

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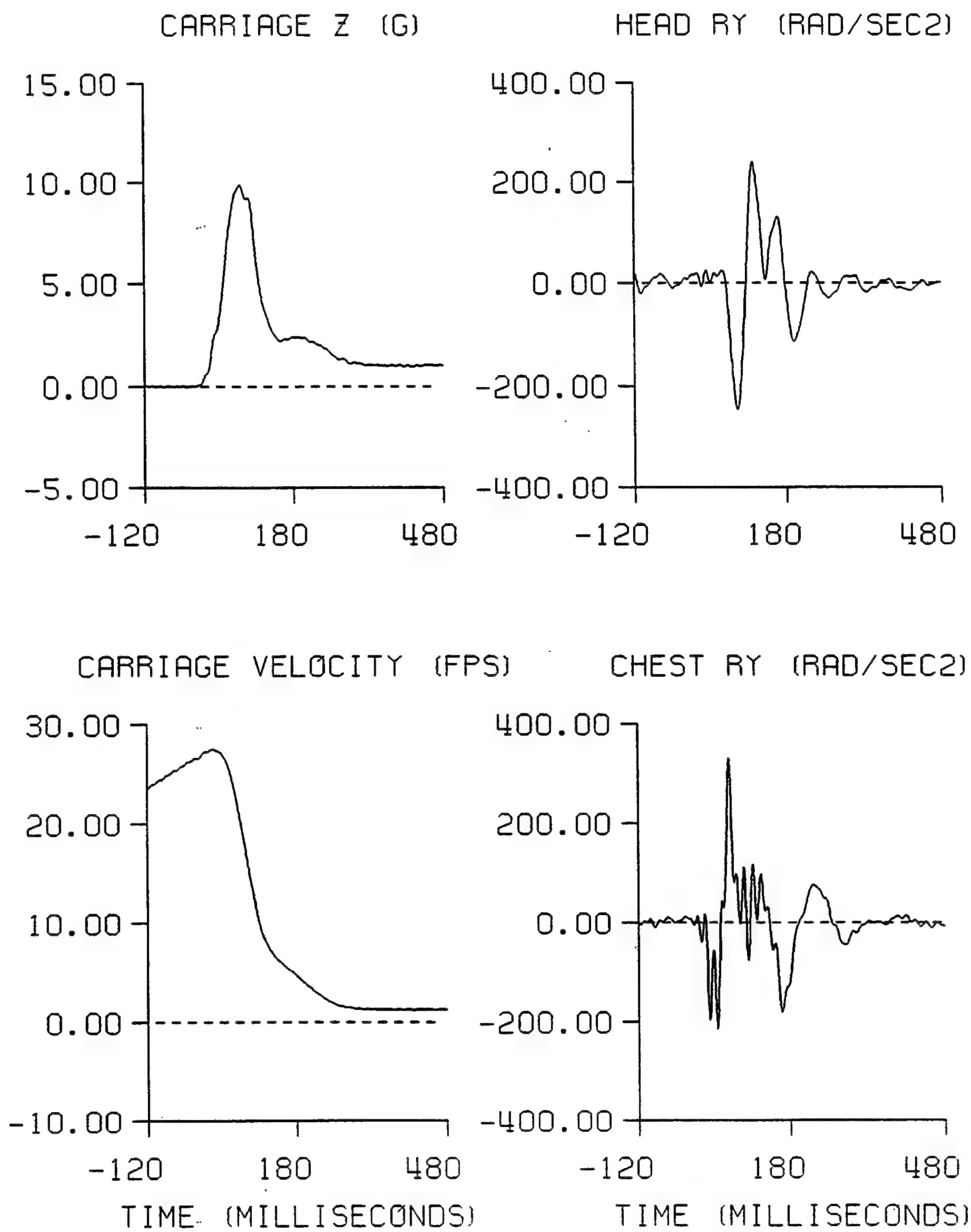
FIP STUDY TEST: 3533 TEST DATE: 15-MAY-1996 SUBJ: B-17 WT: 138.0
NOM G: 10.0 CELL: C

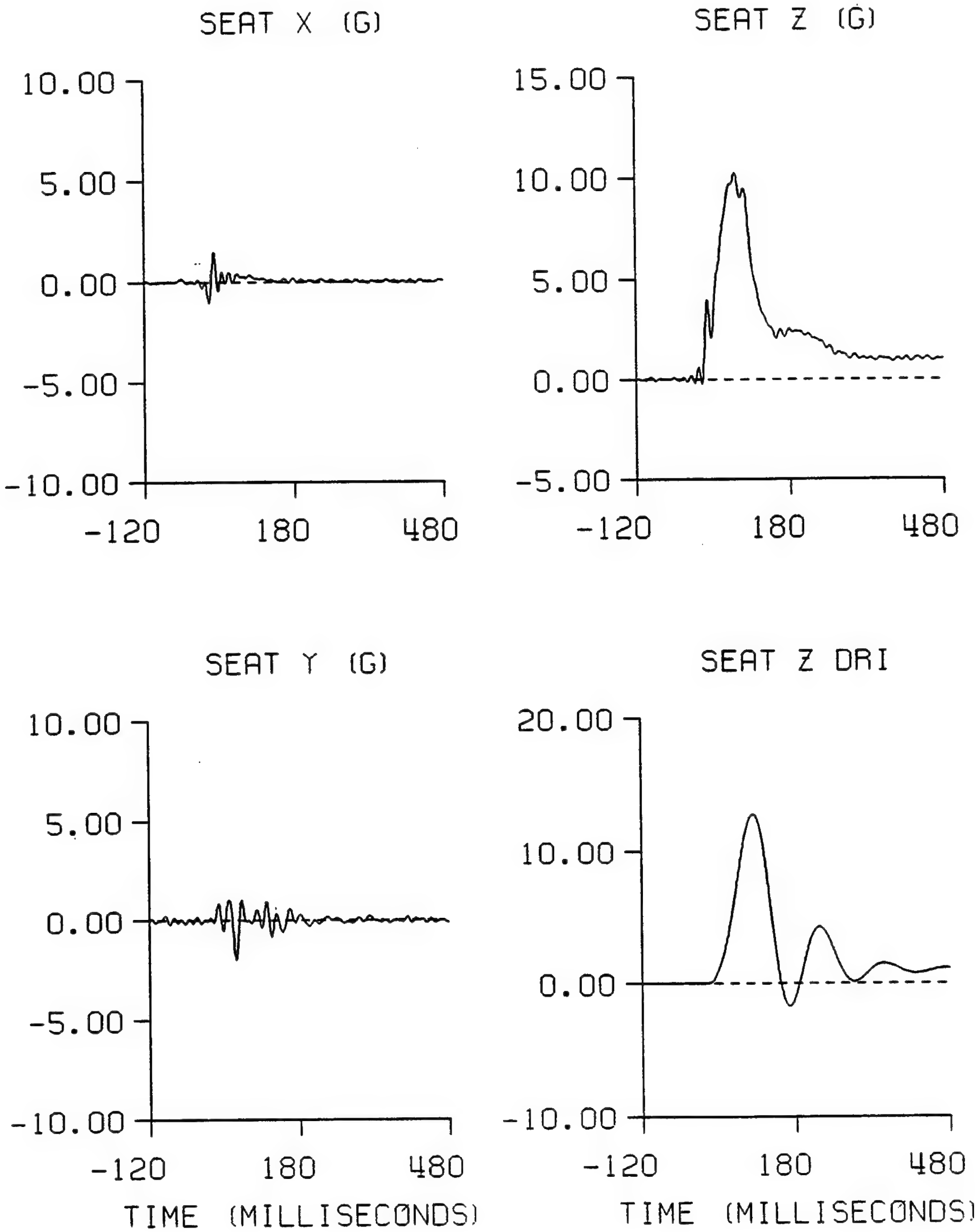
DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
SHOULDER STRAP FORCES (LB)					
X AXIS	-67.83	-24.08	-132.07	474.	105.
Y AXIS	-5.77	-3.07	-17.14	322.	107.
Z AXIS	27.38	110.75	10.73	99.	480.
RESULTANT	73.37	171.96	26.84	103.	476.
LAP FORCES (LB)					
LEFT X AXIS	-90.93	-32.04	-95.39	480.	82.
LEFT Y AXIS	42.39	43.42	13.70	0.	480.
LEFT Z AXIS	-114.90	-36.53	-115.47	480.	0.
LEFT RESULTANT	152.53	154.31	50.49	0.	480.
RIGHT X AXIS	-84.13	-28.26	-86.36	480.	10.
RIGHT Y AXIS	-40.15	-12.26	-40.89	469.	0.
RIGHT Z AXIS	-101.45	-30.20	-103.58	472.	0.
RIGHT RESULTANT	137.77	140.46	43.42	0.	472.
SEAT FORCES (LB)					
LEFT X AXIS	20.39	53.53	10.96	22.	456.
RIGHT X AXIS	-7.55	17.42	-33.63	26.	90.
X AXIS SUM	12.84	67.48	-0.29	23.	90.
Y AXIS	-10.75	26.22	-10.34	88.	7.
LEFT Z AXIS	55.24	254.00	30.57	75.	299.
RIGHT Z AXIS	82.32	342.69	39.04	77.	480.
CENTER Z AXIS	120.33	1285.83	115.96	76.	9.
Z AXIS SUM	257.89	1882.19	197.13	76.	461.
RESULTANT	258.44	1882.35	198.78	76.	461.
Z SUM MINUS TARE	281.99	1667.62	197.06	77.	470.
RESULTANT MINUS TARE	282.49	1667.79	198.83	77.	471.

Page 2 of 2

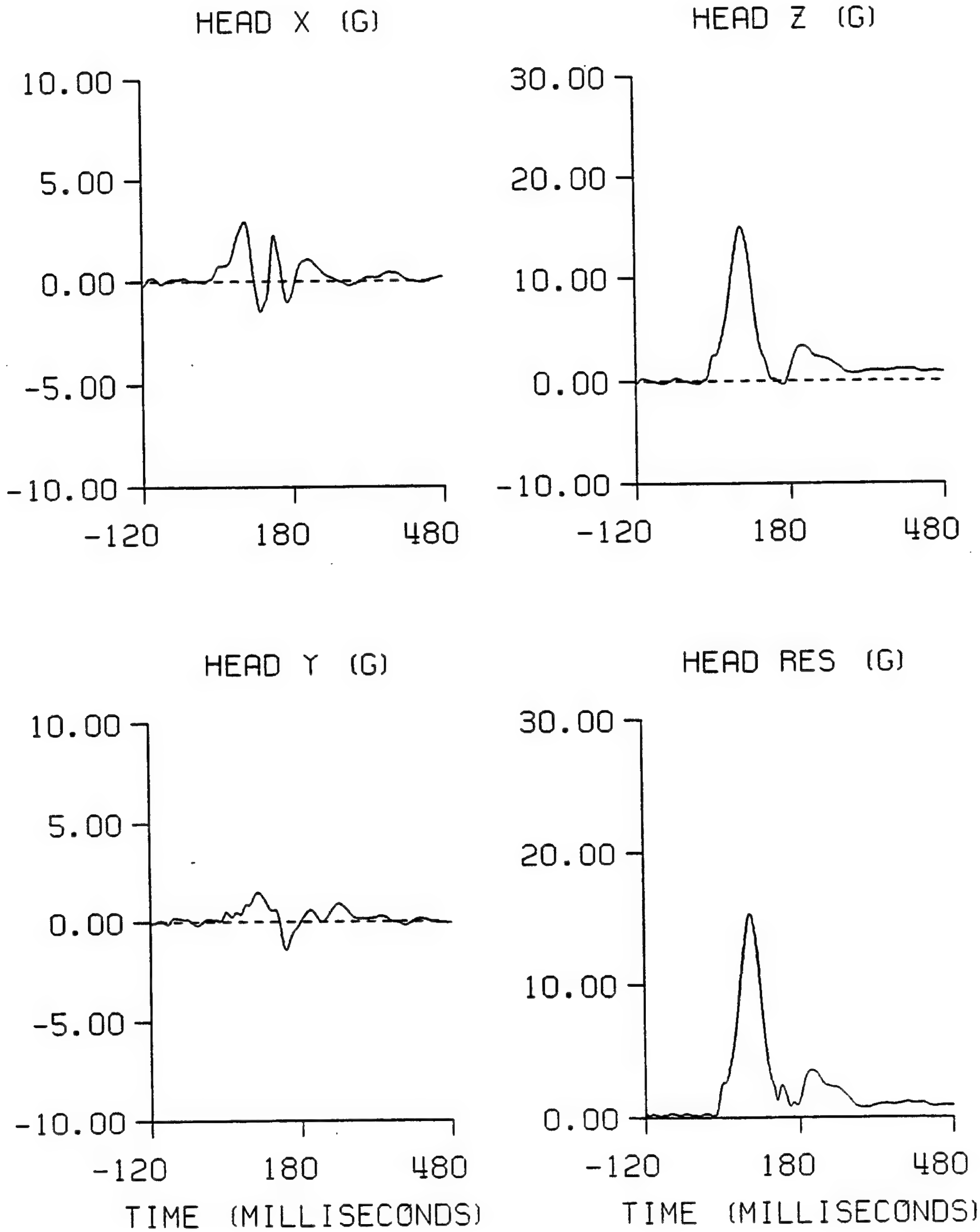
FIP STUDY TEST: 3533 SUBJ: B-17 CELL: C



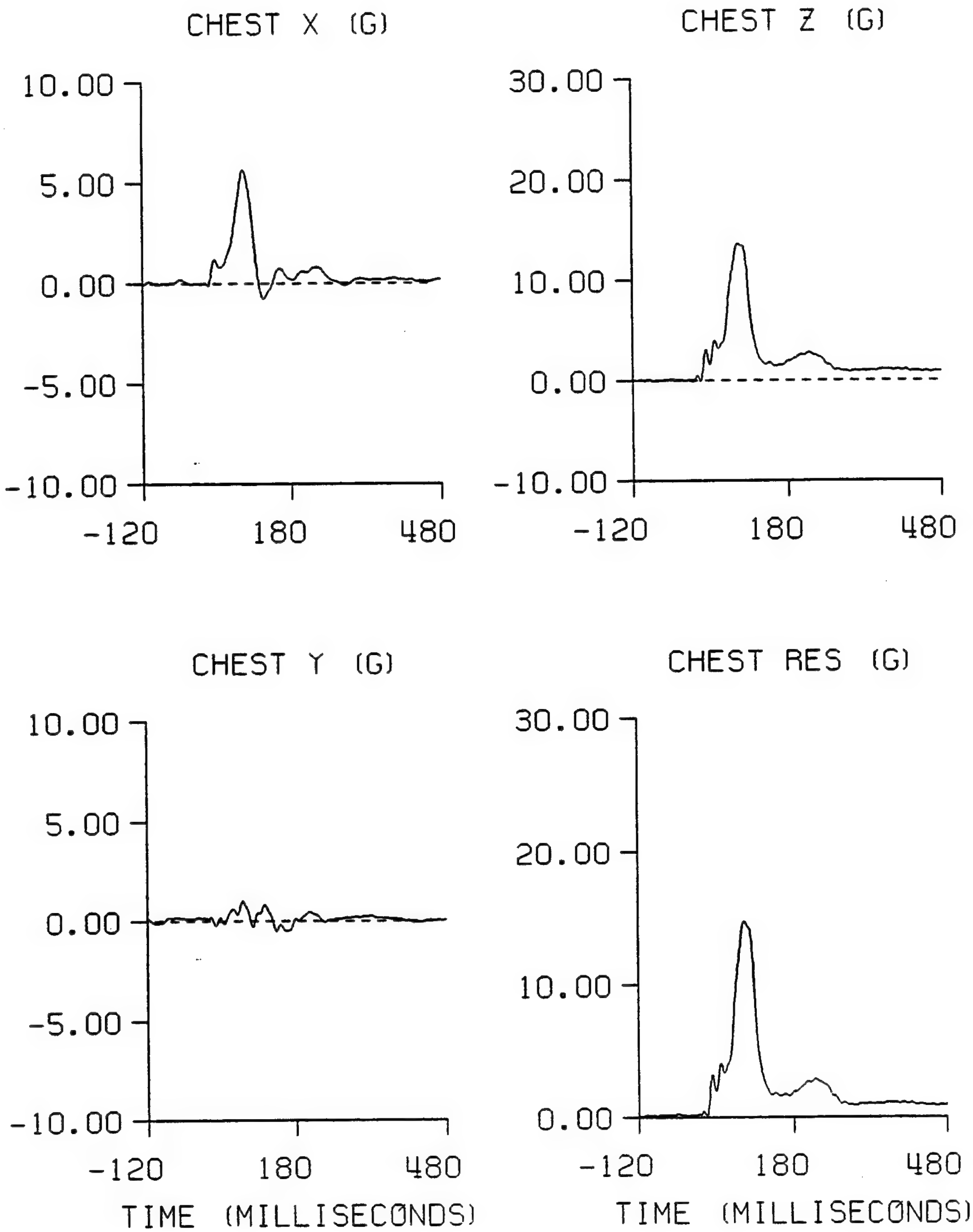
FIP STUDY TEST: 3533 SUBJ: B-17 CELL: C



FIP STUDY TEST: 3533 SUBJ: B-17 CELL: C

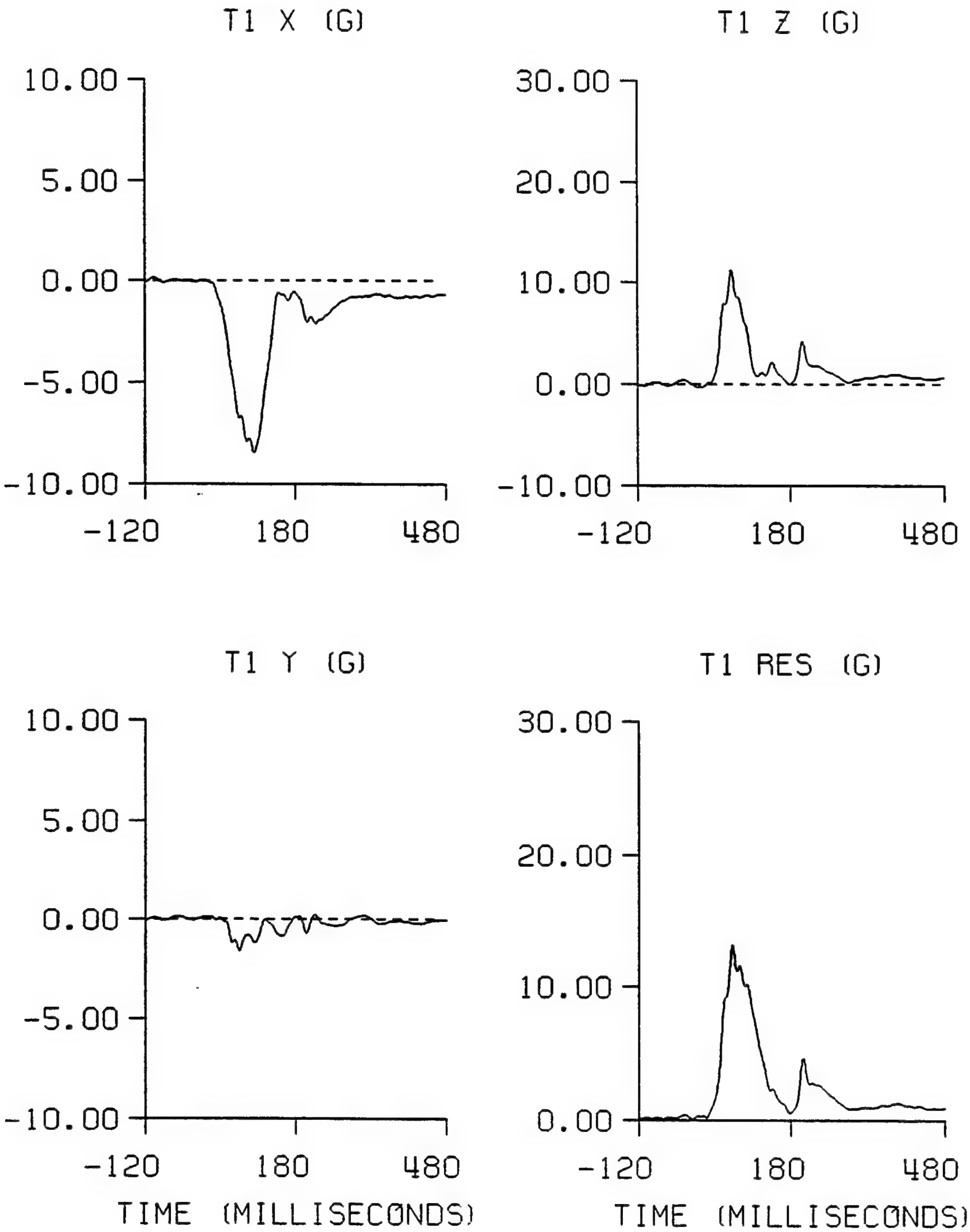


FIP STUDY TEST: 3533 SUBJ: B-17 CELL: C



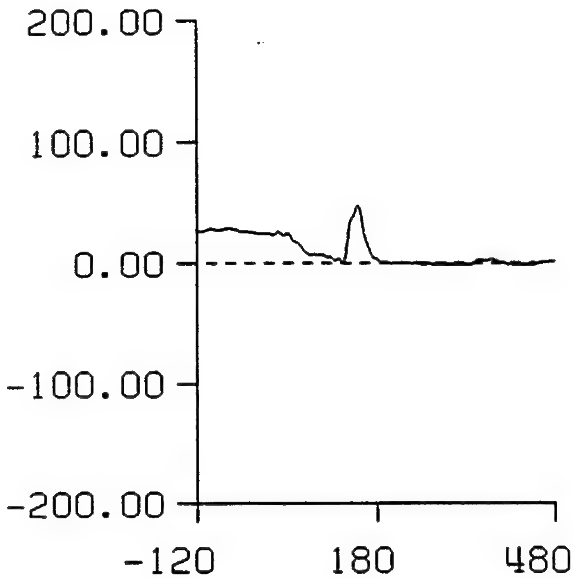
B-6

FIP STUDY TEST: 3533 SUBJ: B-17 CELL: C

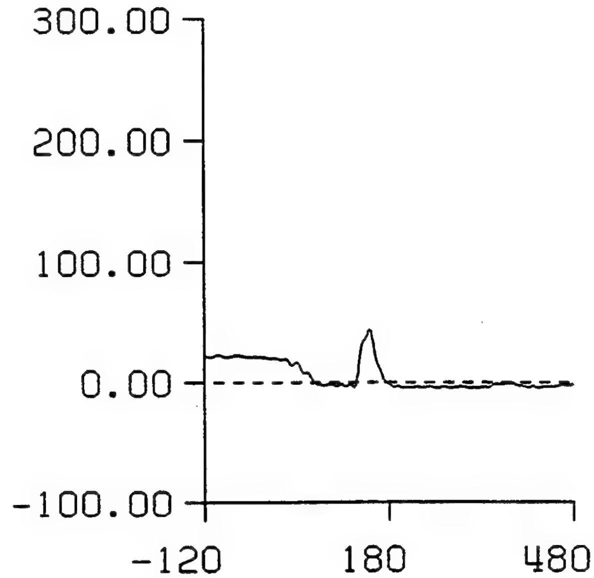


FIP STUDY TEST: 3533 SUBJ: B-17 CELL: C

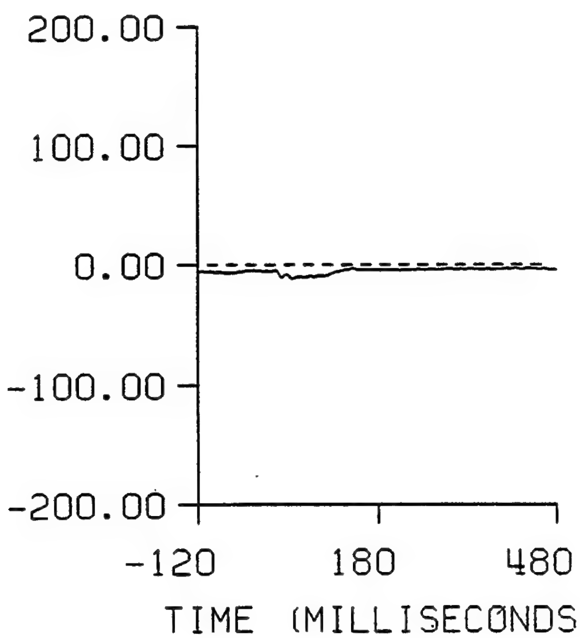
LOWER HEADREST X (LB)



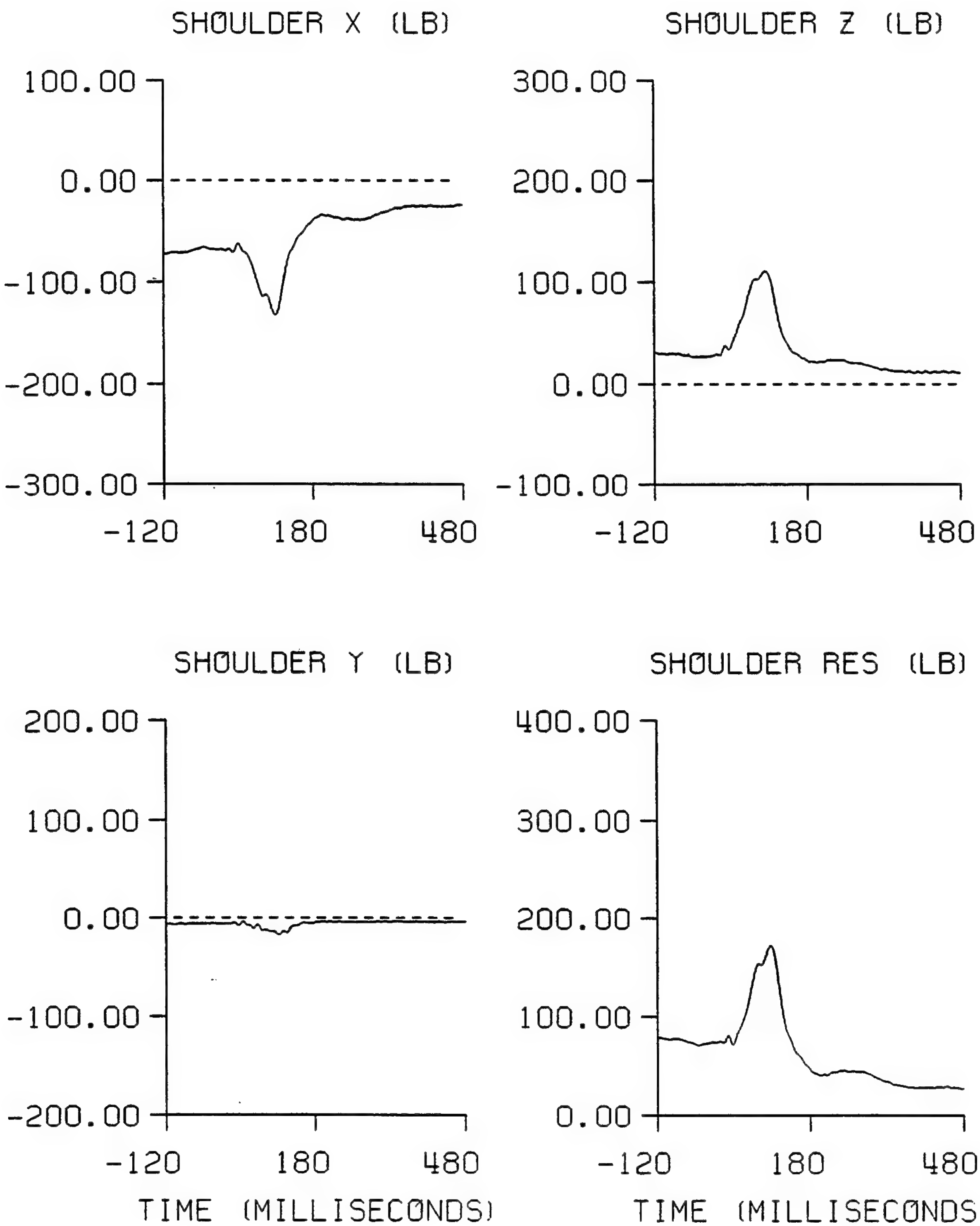
HEADREST X SUM (LB)



UPPER HEADREST X (LB)

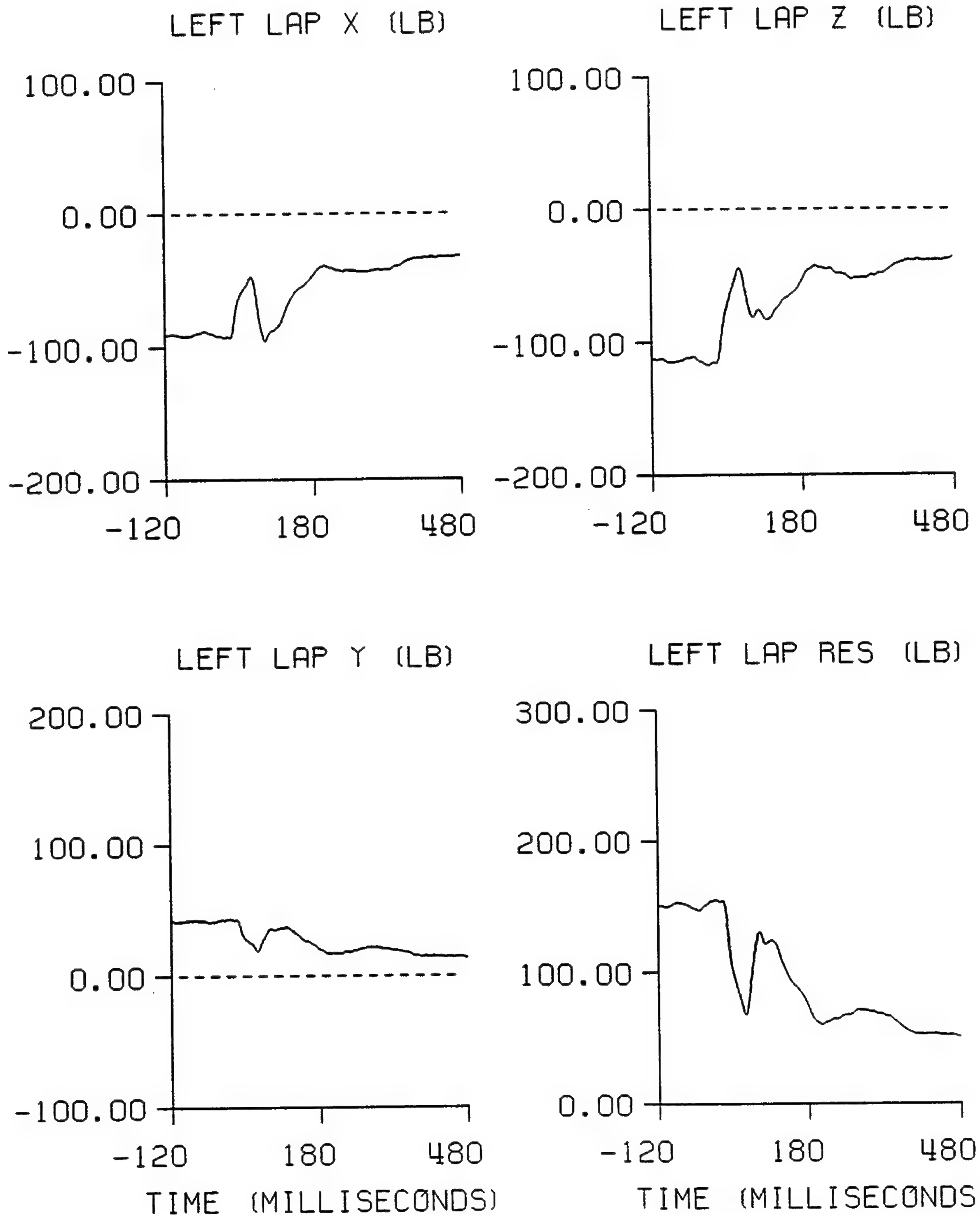


FIP STUDY TEST: 3533 SUBJ: B-17 CELL: C



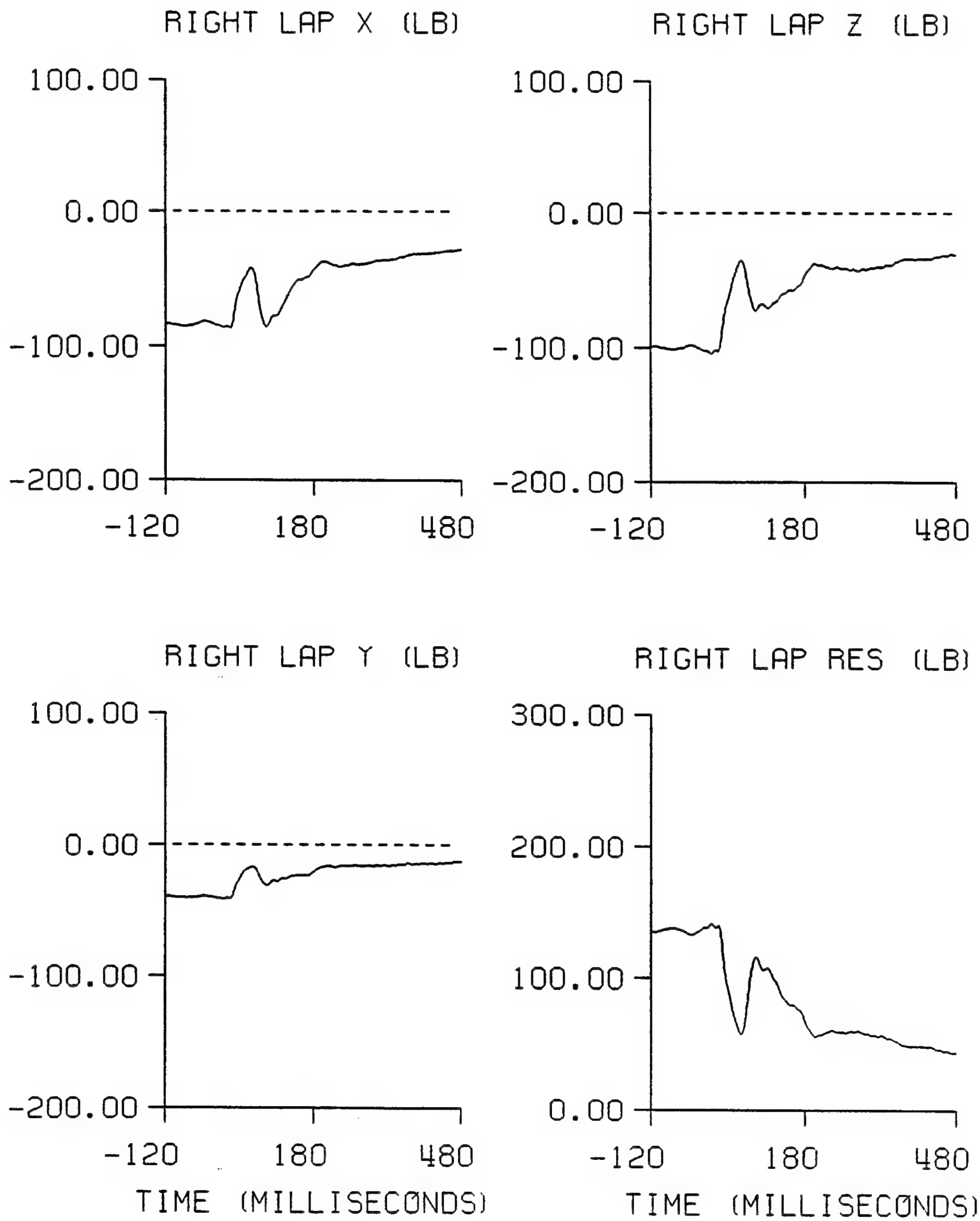
B-9

FIP STUDY TEST: 3533 SUBJ: B-17 CELL: C

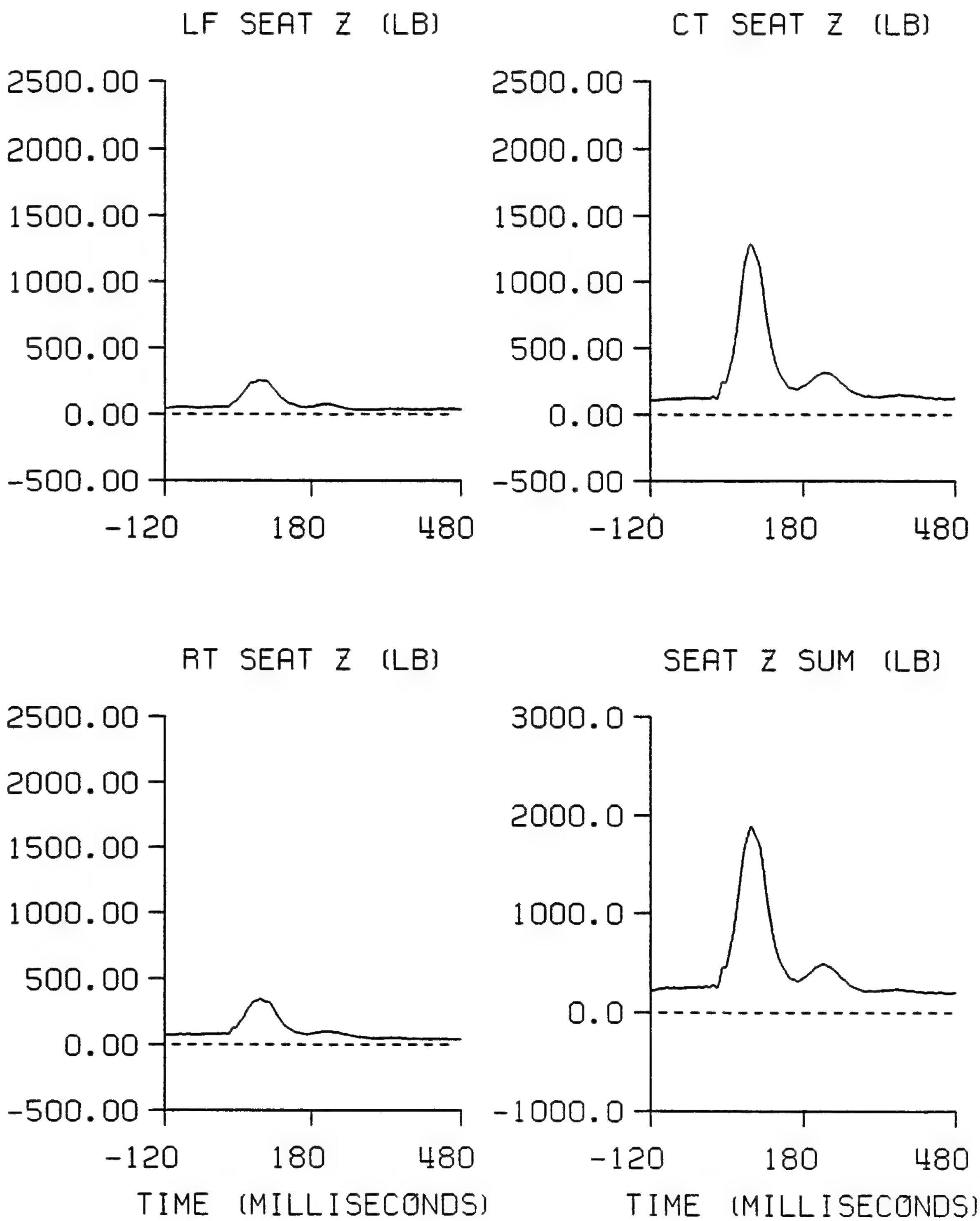


B-10

FIP STUDY TEST: 3533 SUBJ: B-17 CELL: C



FIP STUDY TEST: 3533 SUBJ: B-17 CELL: C



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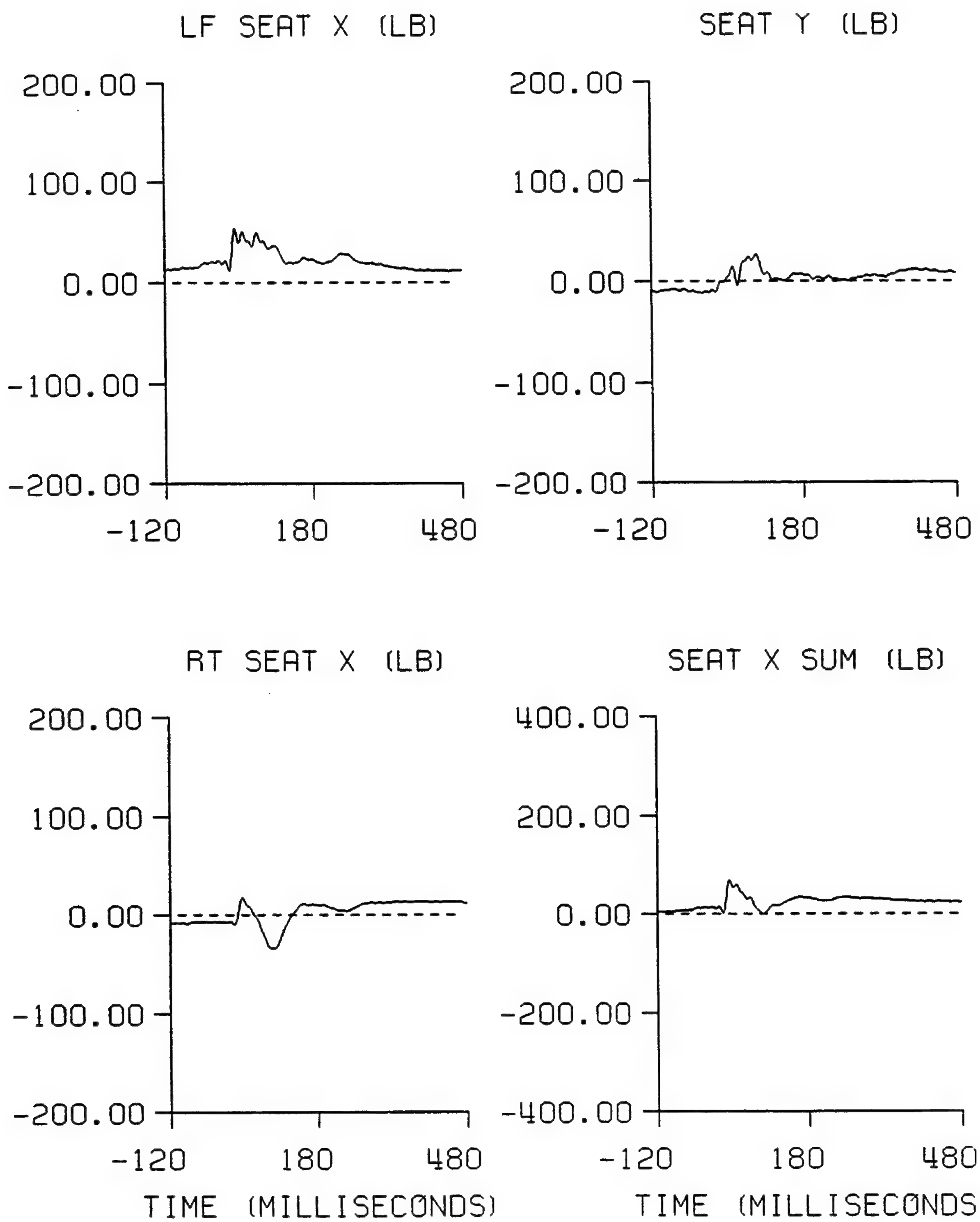
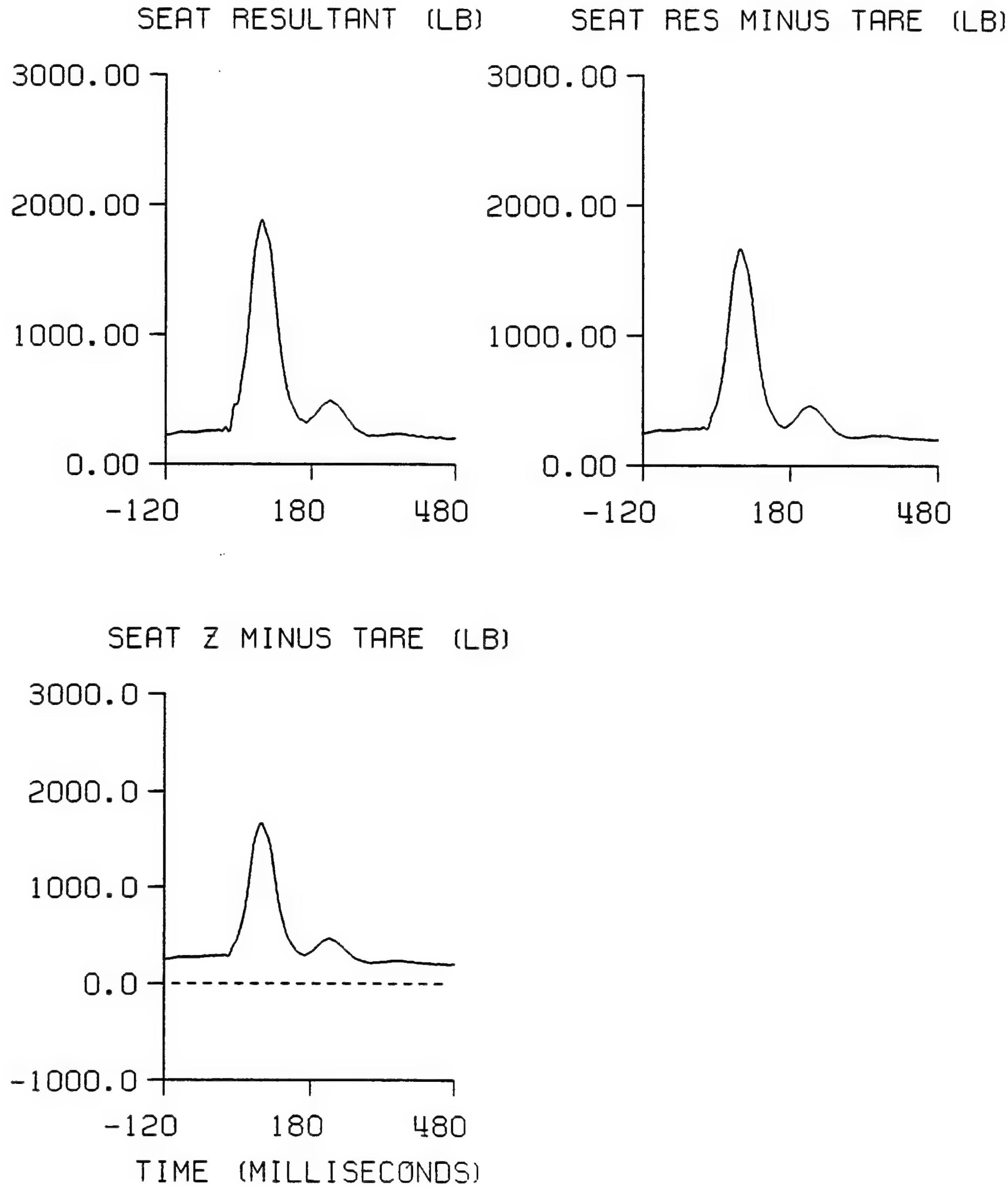


B-13

FIP STUDY TEST: 3533 SUBJ: B-17 CELL: C



FIP STUDY TEST: 3761 TEST DATE: 13-SEP-1996 SUBJ: B-17 WT: 133.0
NOM G: 10.0 CELL: H

DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK TIME (MS)				-124.	
IMPACT RISE TIME (MS)				73.1	
IMPACT DURATION (MS)				146.4	
CARRIAGE Z ACCELERATION (G)	0.07	9.87	0.50	69.	0.
CARRIAGE VELOCITY (FPS)	25.43	26.00	1.13	12.	356.
SEAT ACCELERATION (G)					
X AXIS	0.00	0.60	-0.35	8.	0.
Y AXIS	0.00	1.62	-2.06	65.	52.
Z AXIS	0.02	10.24	0.35	69.	0.
Z AXIS DRI	0.00	12.67	-1.64	95.	166.
HEAD ACCELERATION (G)					
X AXIS	-0.07	2.96	-2.41	80.	117.
Y AXIS	0.10	1.85	-0.98	85.	182.
Z AXIS	0.04	14.53	-0.05	81.	3.
RESULTANT	0.18	14.93	0.06	81.	6.
RY (RAD/SEC2)	-7.57	272.82	-244.78	117.	81.
CHEST ACCELERATION (G)					
X AXIS	0.03	5.20	-0.15	81.	2.
Y AXIS	0.11	0.32	-1.02	122.	69.
Z AXIS	-0.02	13.65	-0.03	93.	5.
RESULTANT	0.12	14.08	0.18	91.	6.
RY (RAD/SEC2)	-12.53	492.60	-233.68	63.	166.
T1 ACCELERATION (G)					
X AXIS	0.07	3.39	-2.88	79.	103.
Y AXIS	0.13	0.52	-3.53	165.	56.
Z AXIS	0.00	14.47	-0.05	58.	4.
RESULTANT	0.16	14.78	0.18	58.	0.
HEADREST X FORCES (LB)					
LOWER	1.35	18.69	-1.16	172.	385.
UPPER	2.15	4.18	-7.32	169.	68.
SUM	3.50	22.72	-1.61	171.	68.

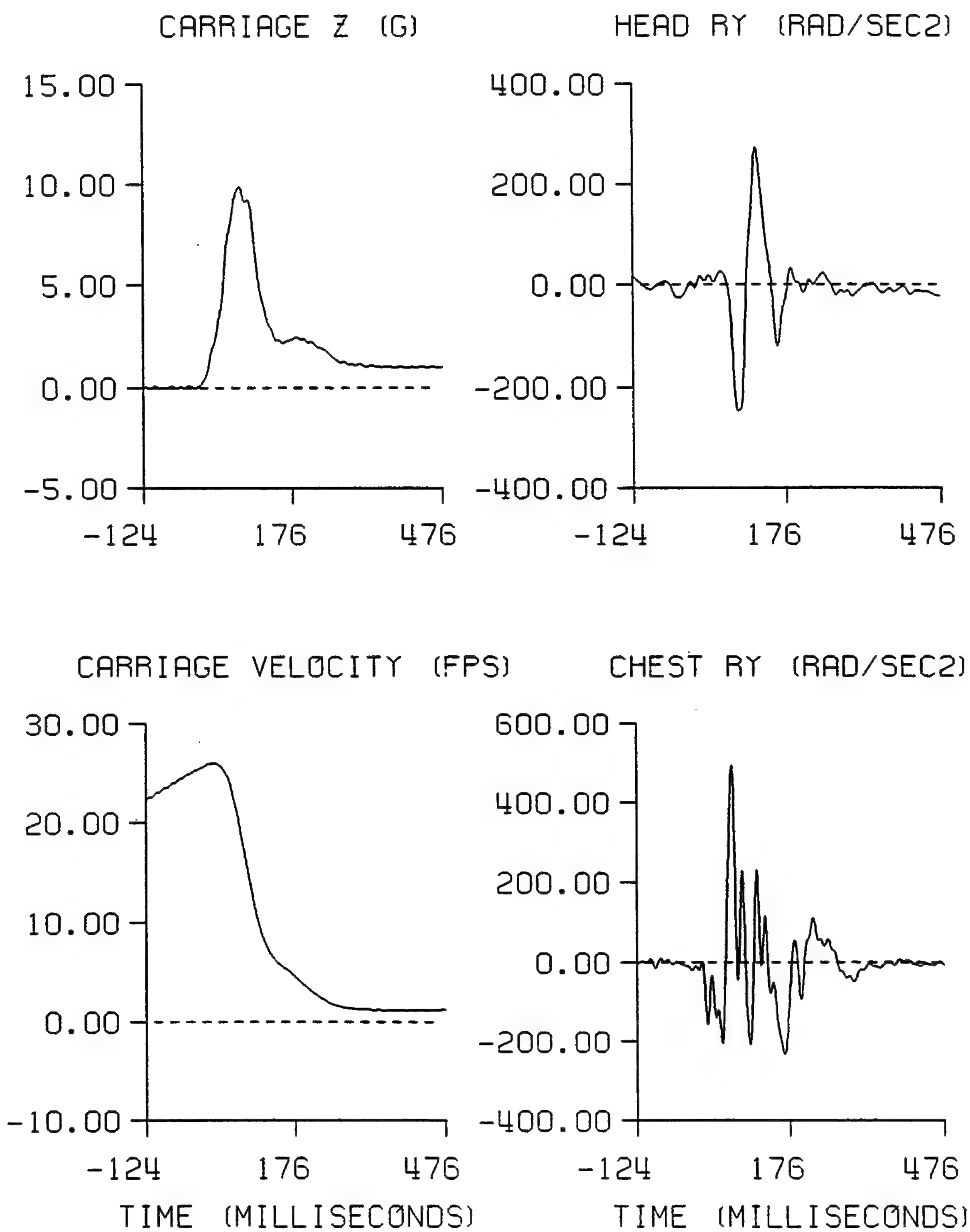
Page 1 of 2

FIP STUDY TEST: 3761 TEST DATE: 13-SEP-1996 SUBJ: B-17 WT: 133.0
NOM G: 10.0 CELL: H

DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
SHOULDER STRAP FORCES (LB)					
X AXIS	-54.65	-20.68	-96.90	465.	105.
Y AXIS	2.11	4.15	-7.37	378.	104.
Z AXIS	12.87	77.26	8.04	73.	324.
RESULTANT	56.19	120.66	22.72	74.	466.
LAP FORCES (LB)					
LEFT X AXIS	-93.24	-21.47	-93.50	456.	0.
LEFT Y AXIS	35.71	34.65	6.66	2.	461.
LEFT Z AXIS	-109.69	-24.75	-108.41	477.	0.
LEFT RESULTANT	148.33	147.29	33.60	0.	459.
RIGHT X AXIS	-87.14	-19.95	-87.36	463.	0.
RIGHT Y AXIS	-24.99	-3.23	-24.81	463.	0.
RIGHT Z AXIS	-104.81	-23.10	-103.69	466.	2.
RIGHT RESULTANT	138.57	137.71	30.73	0.	465.
SEAT FORCES (LB)					
LEFT X AXIS	1.57	4.44	-2.01	7.	48.
RIGHT X AXIS	-1.35	16.35	-78.21	334.	84.
X AXIS SUM	0.22	14.92	-79.25	335.	83.
Y AXIS	7.11	70.52	3.28	66.	439.
LEFT Z AXIS	14.61	271.90	14.97	76.	468.
RIGHT Z AXIS	65.09	454.93	31.23	76.	367.
CENTER Z AXIS	130.30	1244.34	131.35	74.	470.
Z AXIS SUM	210.00	1970.54	177.95	75.	470.
RESULTANT	210.12	1972.74	178.23	75.	470.
Z SUM MINUS TARE	233.39	1766.86	178.62	76.	472.
RESULTANT MINUS TARE	233.51	1769.30	178.92	76.	472.

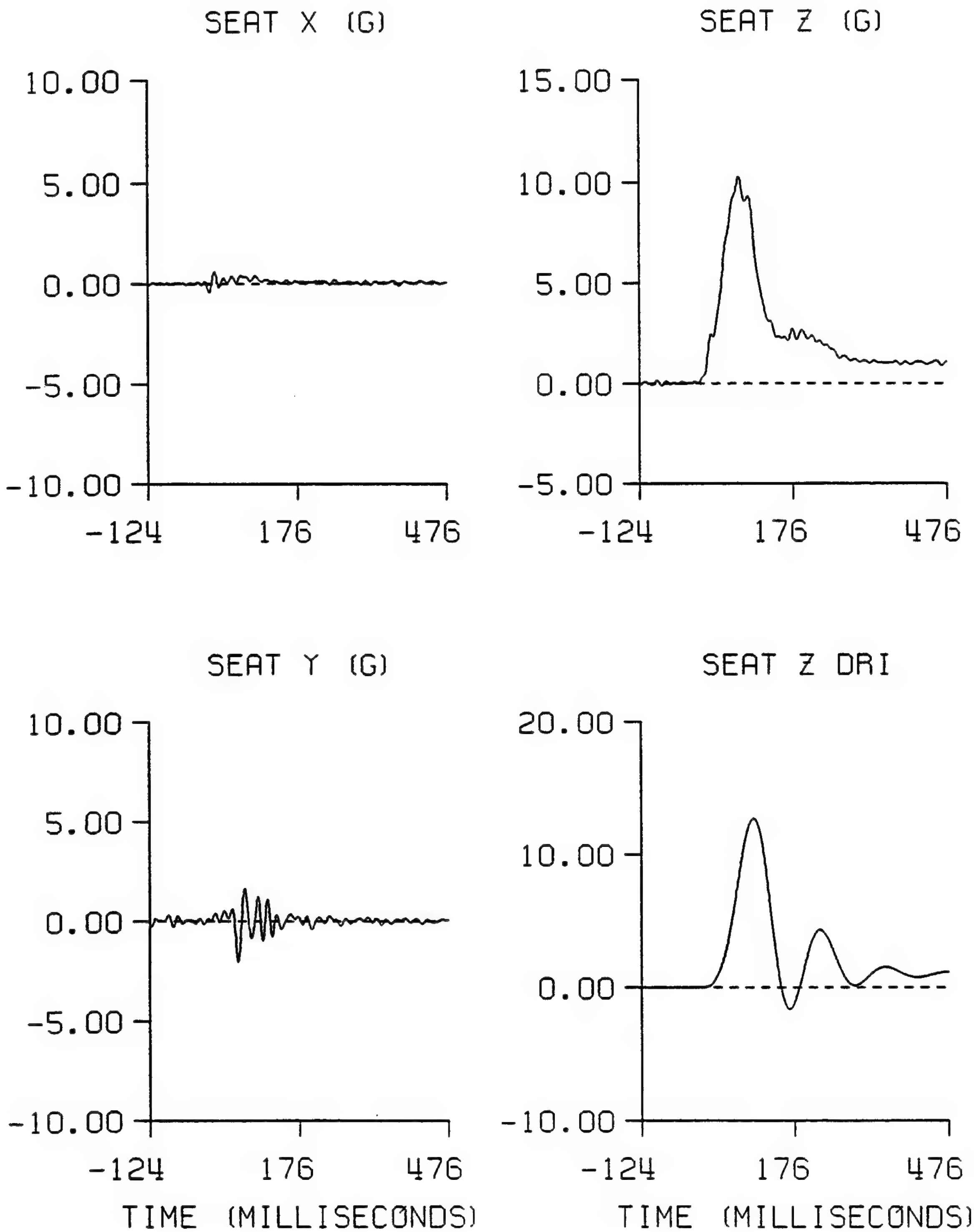
Page 2 of 2

FIP STUDY TEST: 3761 SUBJ: B-17 CELL: H

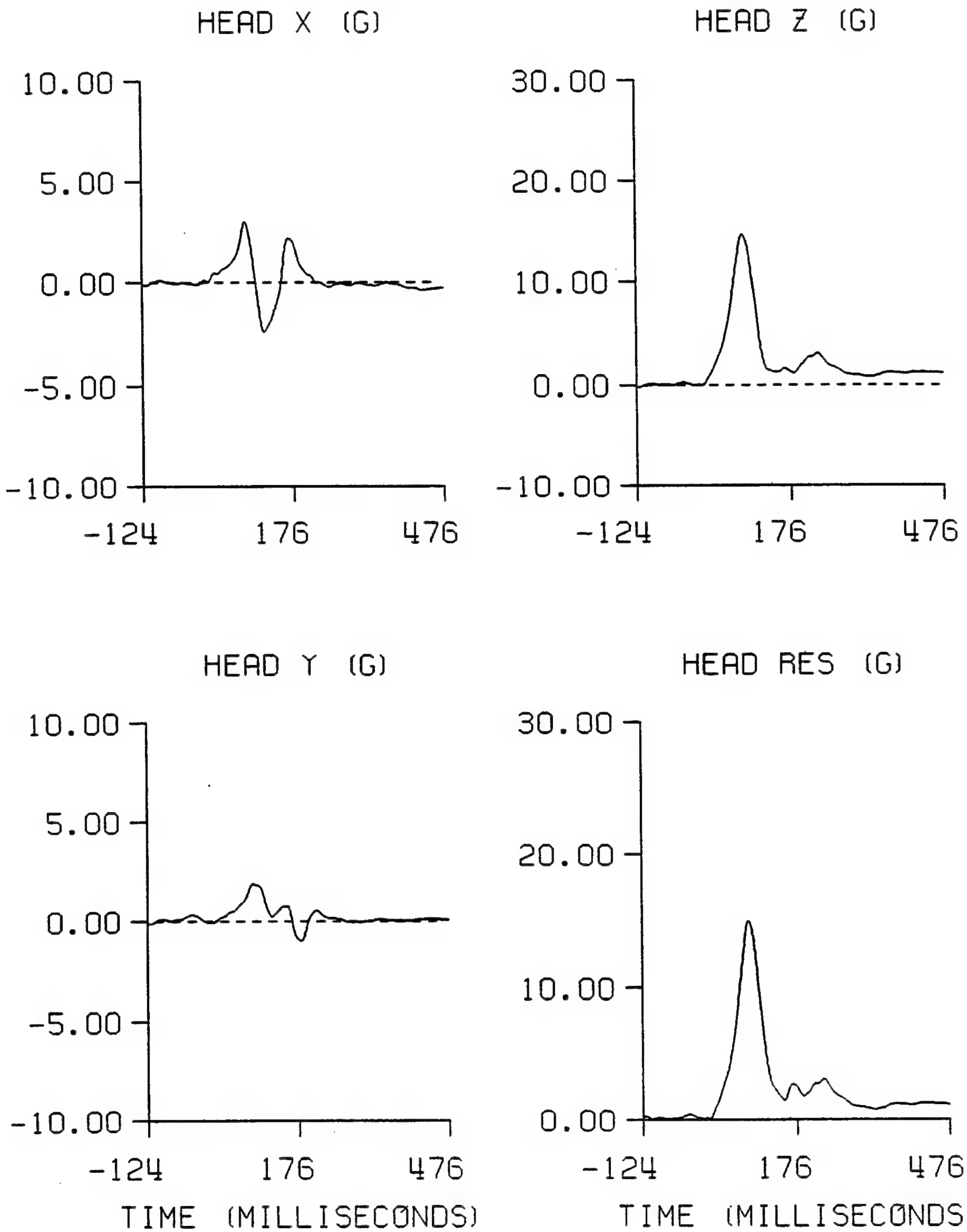


B-17

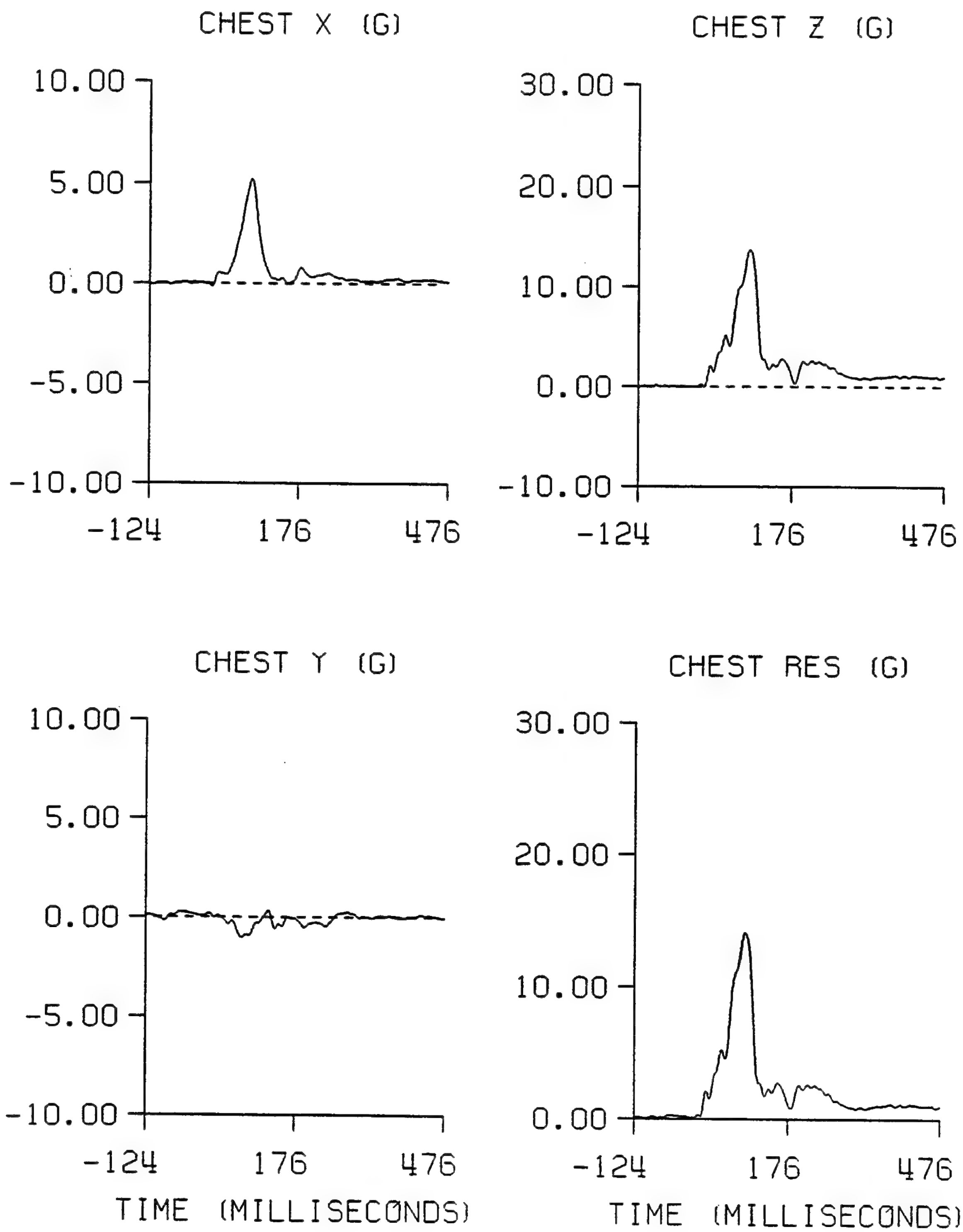
FIP STUDY TEST: 3761 SUBJ: B-17 CELL: H



FIP STUDY TEST: 3761 SUBJ: B-17 CELL: H

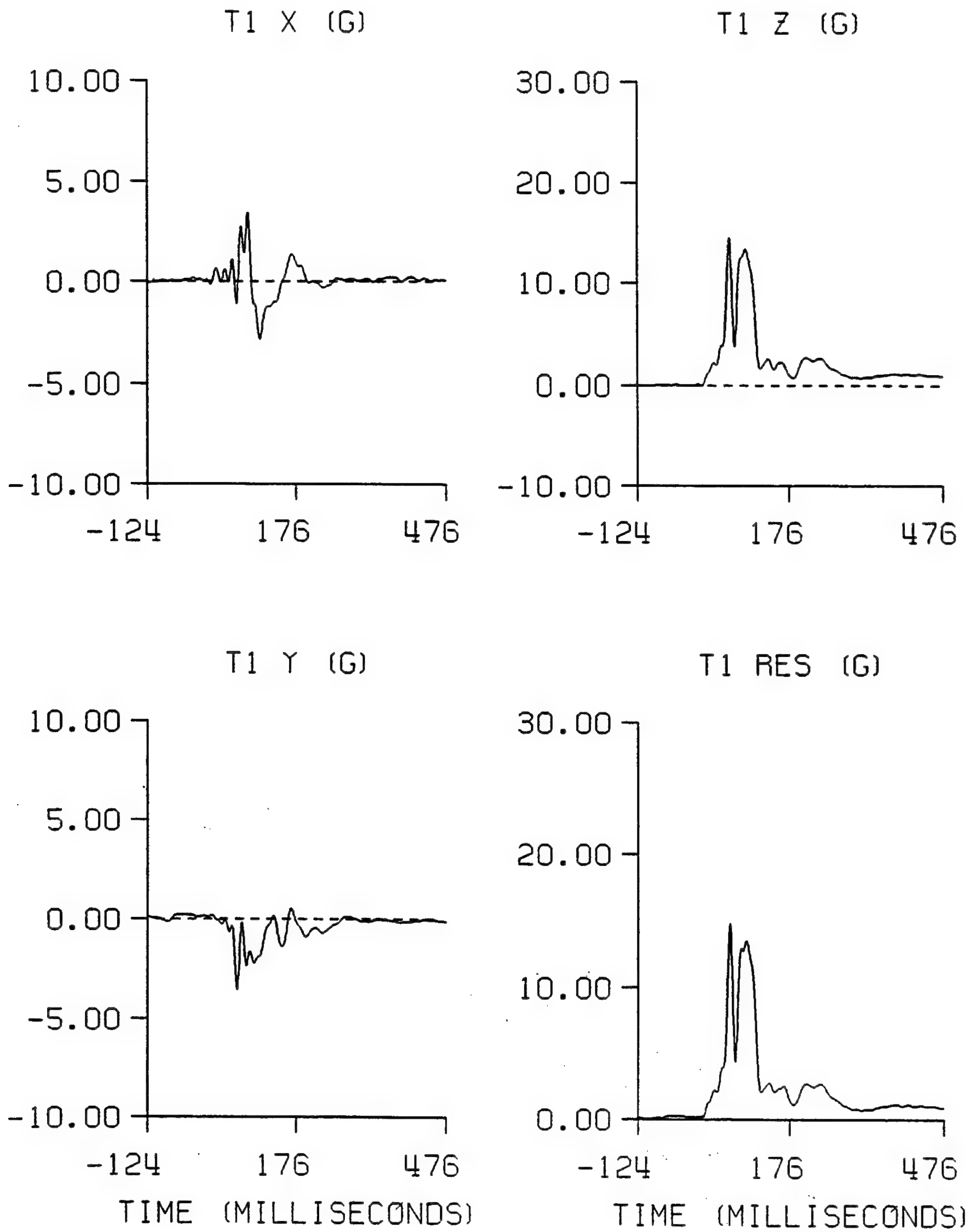


FIP STUDY TEST: 3761 SUBJ: B-17 CELL: H

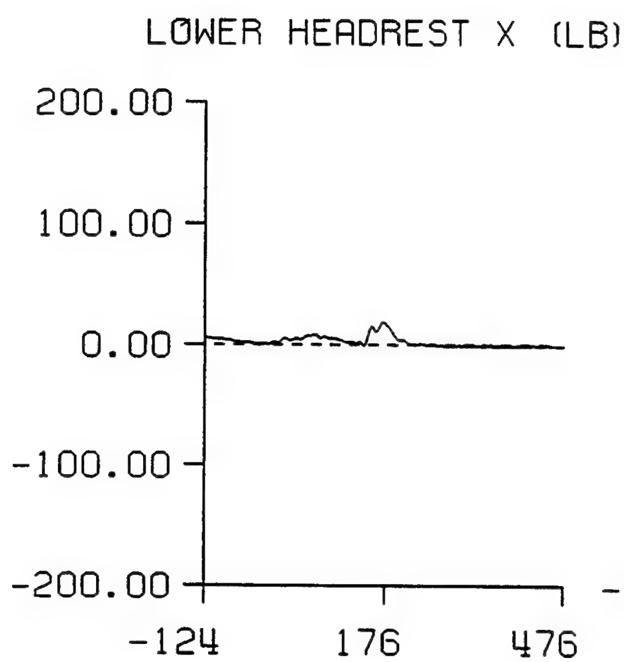


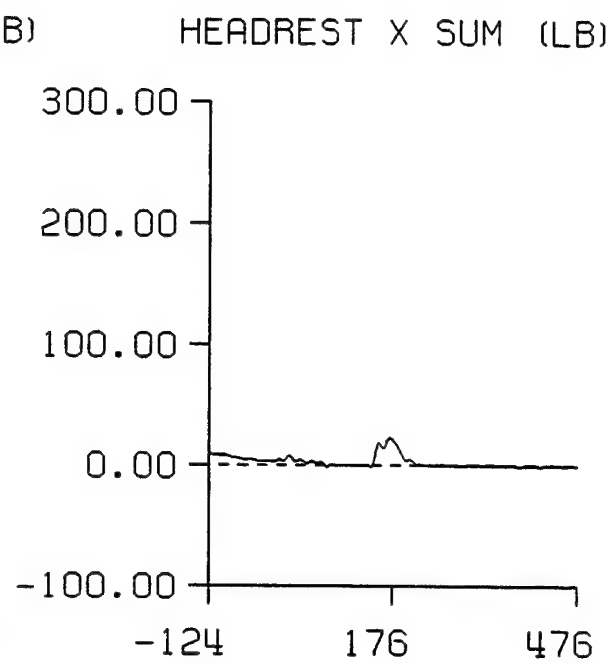
B-20

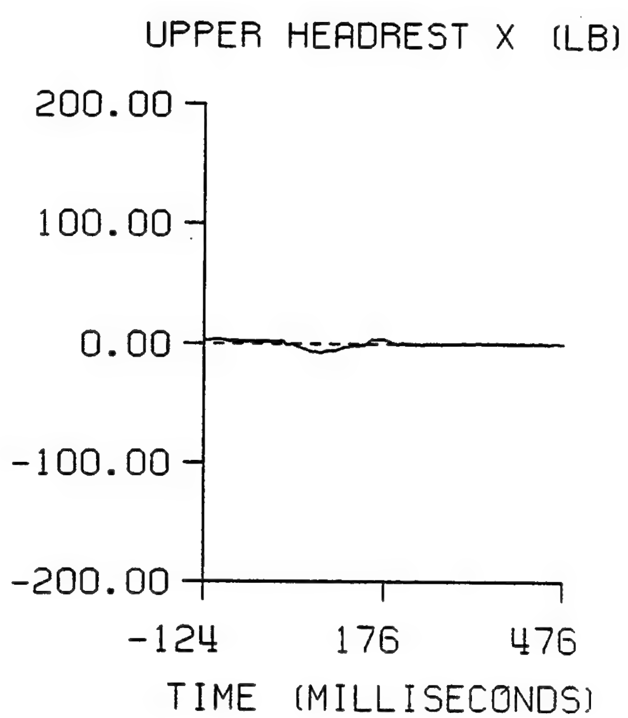
FIP STUDY TEST: 3761 SUBJ: B-17 CELL: H



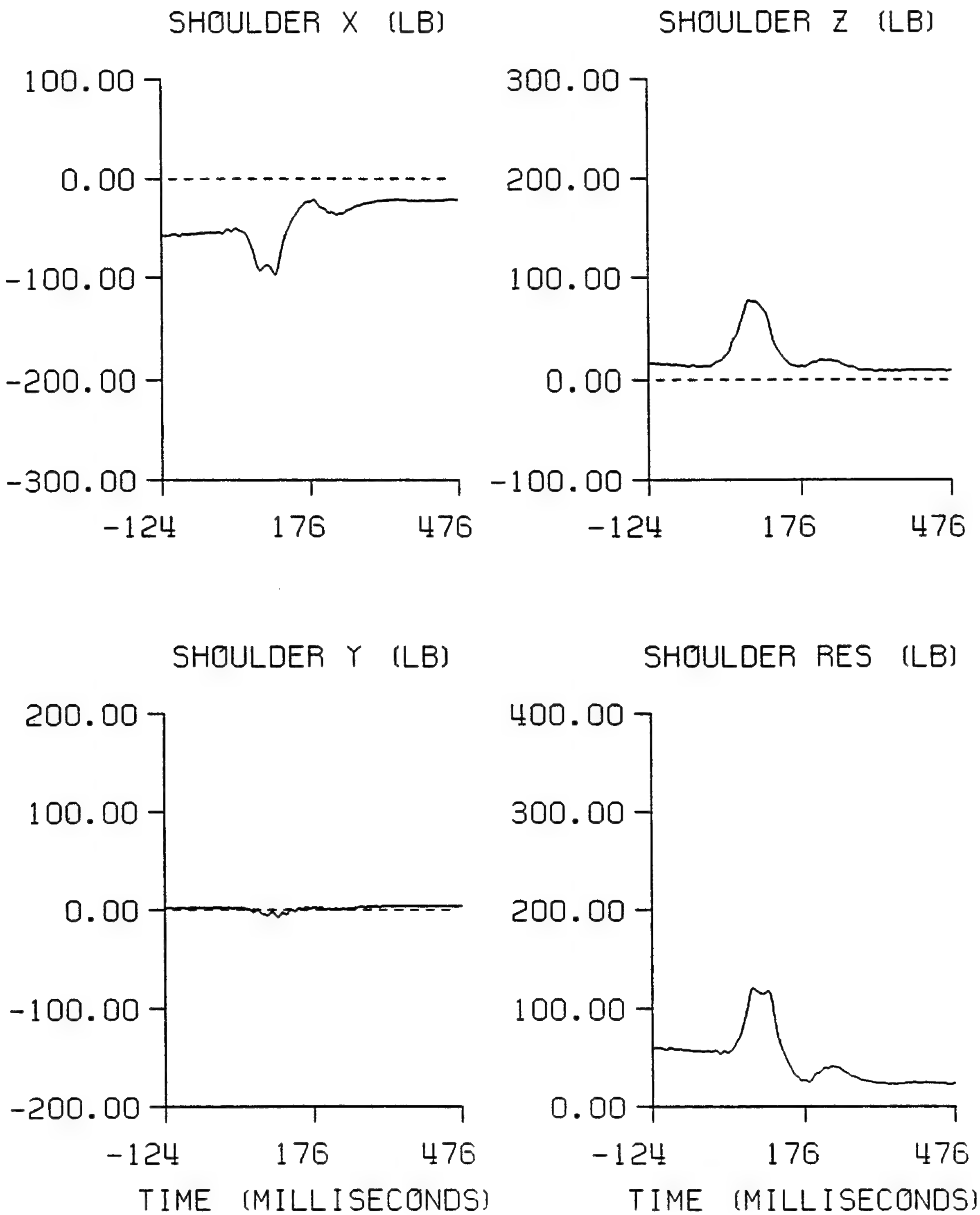
FIP STUDY TEST: 3761 SUBJ: B-17 CELL: H





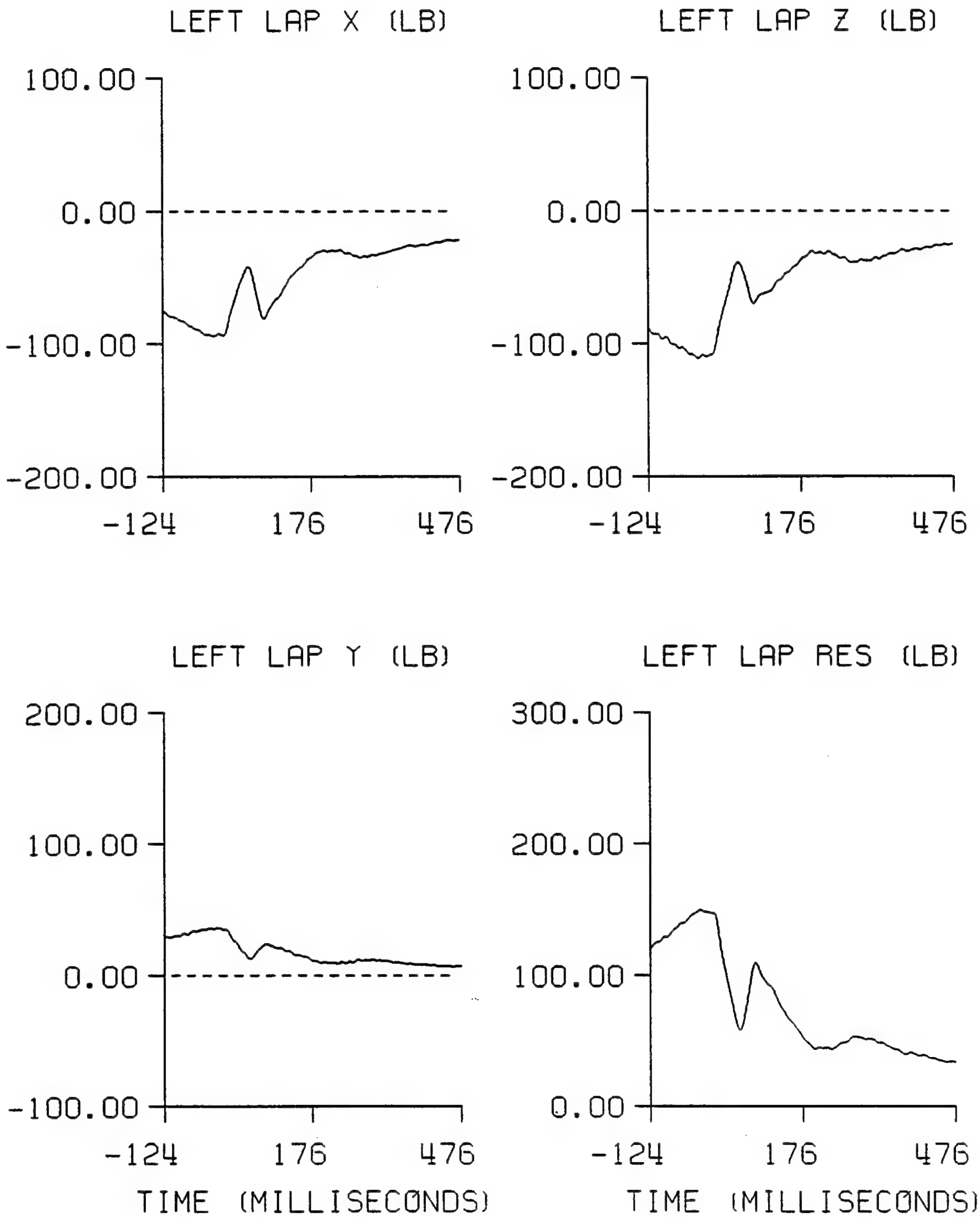


FIP STUDY TEST: 3761 SUBJ: B-17 CELL: H

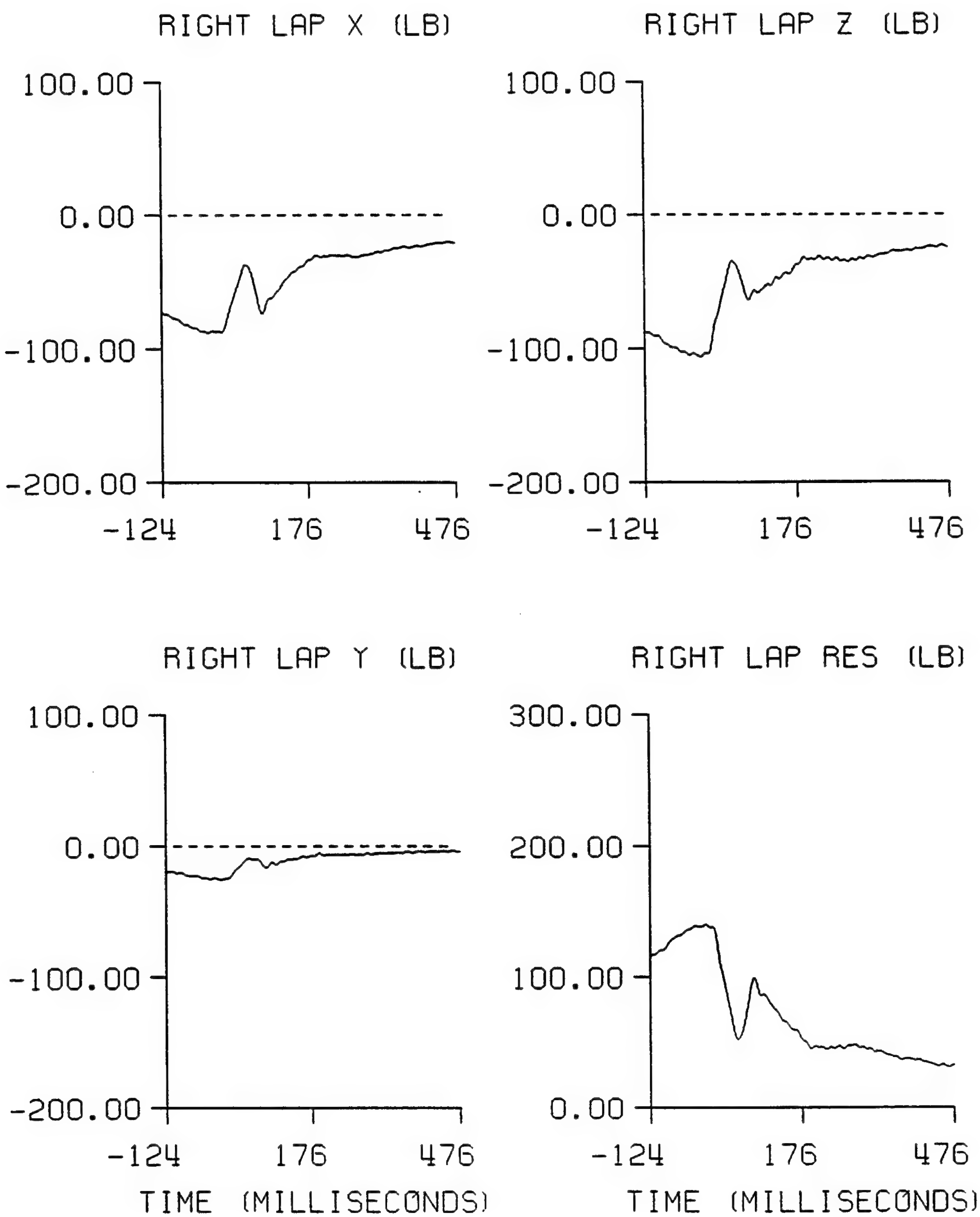


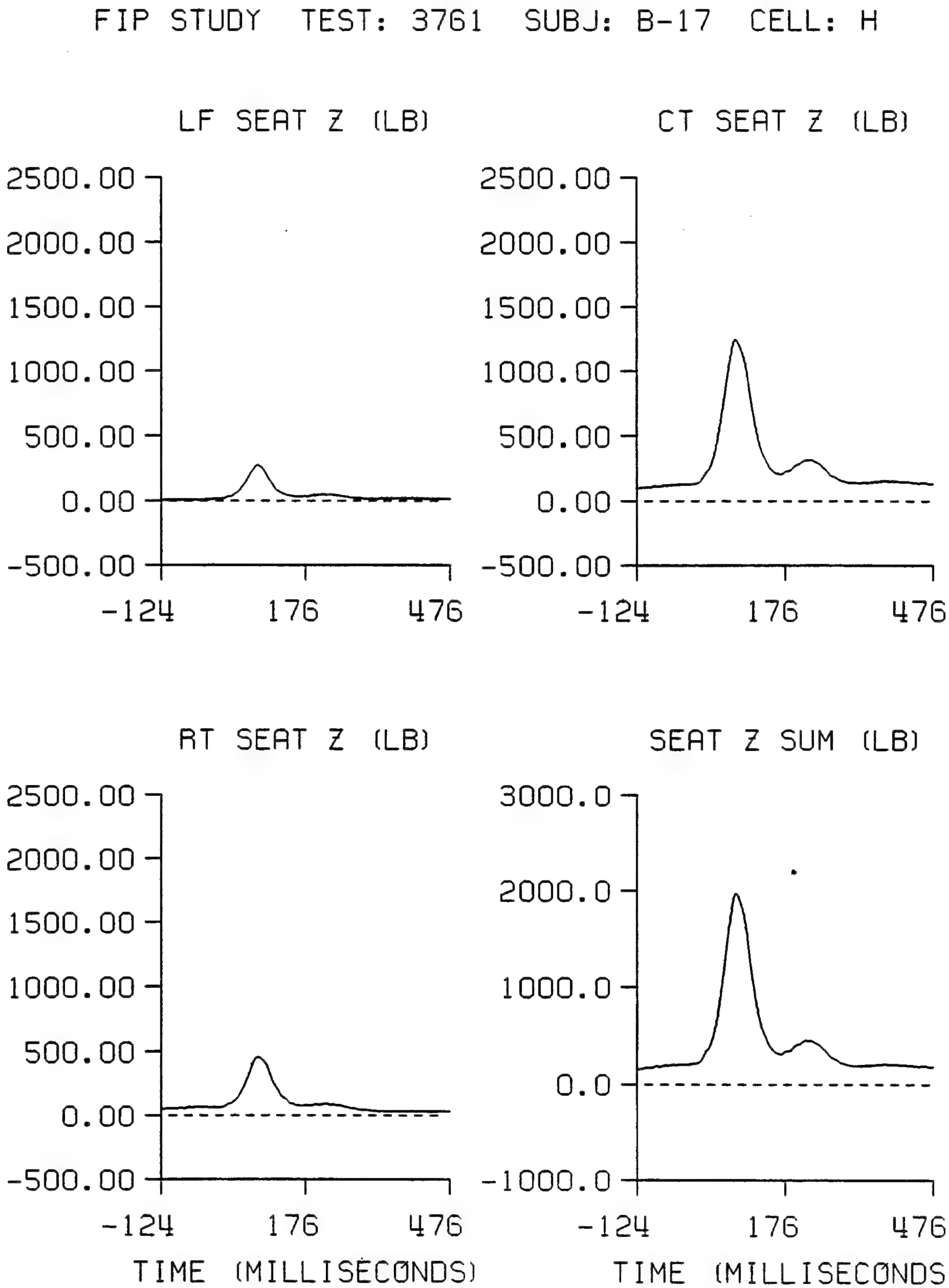
B-23

FIP STUDY TEST: 3761 SUBJ: B-17 CELL: H

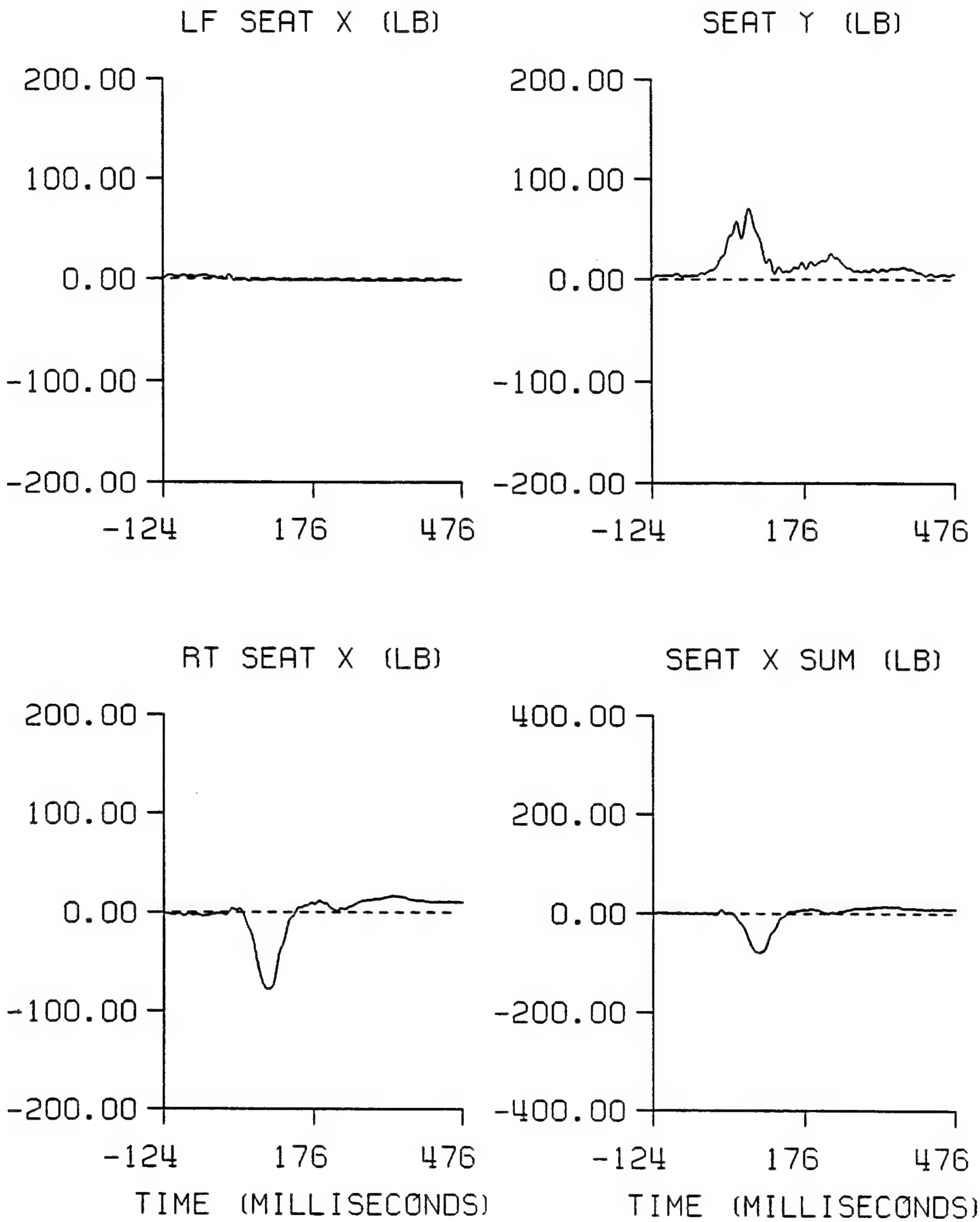


FIP STUDY TEST: 3761 SUBJ: B-17 CELL: H

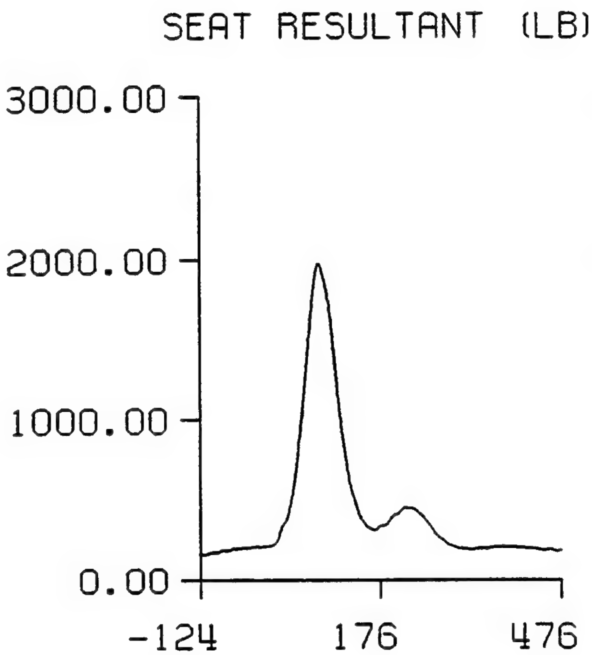


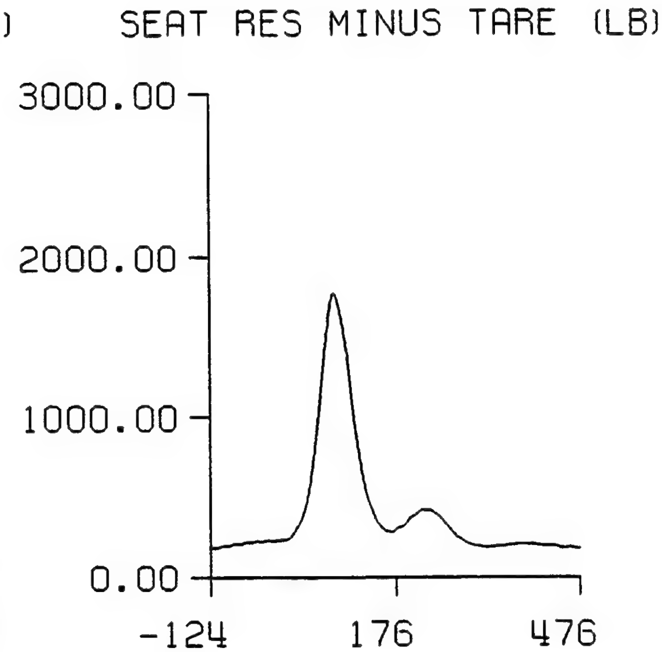

FIP STUDY TEST: 3761 SUBJ: B-17 CELL: H
LF SEAT Z (LB)
CT SEAT Z (LB)
RT SEAT Z (LB)
SEAT Z SUM (LB)
2500.00
2000.00
1500.00
1000.00
500.00
0.00
-500.00
3000.0
2000.0
1000.0
0.0
-1000.0
-124
176
476
TIME (MILLISECONDS)

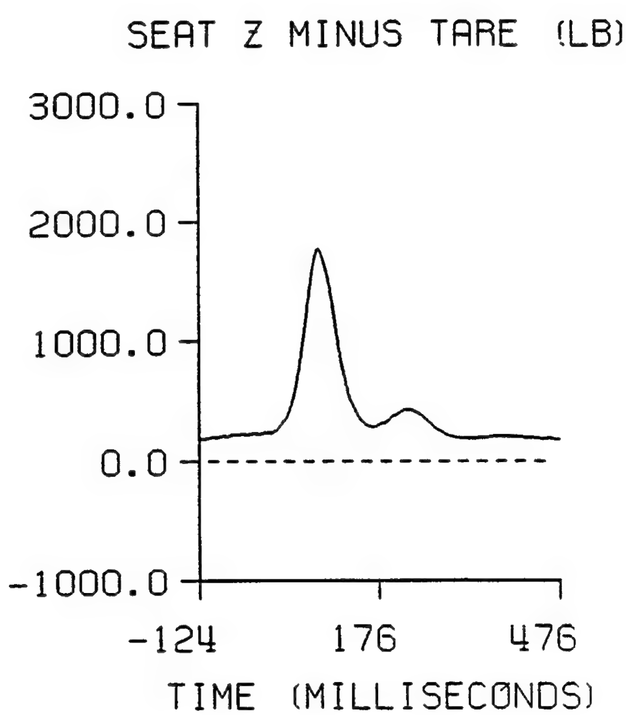
FIP STUDY TEST: 3761 SUBJ: B-17 CELL: H



FIP STUDY   TEST: 3761   SUBJ: B-17   CELL: H







FIP STUDY TEST: 3768 TEST DATE: 17-SEP-1996 SUBJ: B-17 WT: 133.0
NOM G: 10.0 CELL: I

DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK TIME (MS)				-120.	
IMPACT RISE TIME (MS)				74.1	
IMPACT DURATION (MS)				147.9	
CARRIAGE Z ACCELERATION (G)	0.05	9.84	0.52	71.	0.
CARRIAGE VELOCITY (FPS)	25.41	26.04	1.16	7.	370.
SEAT ACCELERATION (G)					
X AXIS	-0.01	1.11	-0.81	16.	7.
Y AXIS	0.05	1.40	-2.40	64.	52.
Z AXIS	0.05	10.20	-0.05	73.	5.
Z AXIS DRI	0.01	12.63	-1.57	96.	167.
HEAD ACCELERATION (G)					
X AXIS	-0.02	2.39	-1.95	82.	118.
Y AXIS	-0.01	1.28	-0.28	87.	207.
Z AXIS	0.04	14.37	-0.03	86.	1.
RESULTANT	0.12	14.61	0.03	86.	12.
RY (RAD/SEC2)	5.32	239.89	-173.79	114.	85.
CHEST ACCELERATION (G)					
X AXIS	-0.05	3.88	-0.60	86.	132.
Y AXIS	0.04	1.35	-2.15	112.	88.
Z AXIS	0.10	13.48	-0.21	79.	9.
RESULTANT	0.13	13.99	0.04	79.	0.
RY (RAD/SEC2)	2.46	742.06	-392.82	71.	102.
T1 ACCELERATION (G)					
X AXIS	-0.09	2.79	-2.71	74.	109.
Y AXIS	0.00	0.59	-3.22	110.	97.
Z AXIS	0.05	16.62	-0.08	68.	13.
RESULTANT	0.11	16.70	0.03	69.	10.
HEADREST X FORCES (LB)					
LOWER	0.40	8.83	-0.05	198.	473.
UPPER	1.19	1.40	-7.81	5.	73.
SUM	1.59	7.37	-1.25	198.	73.

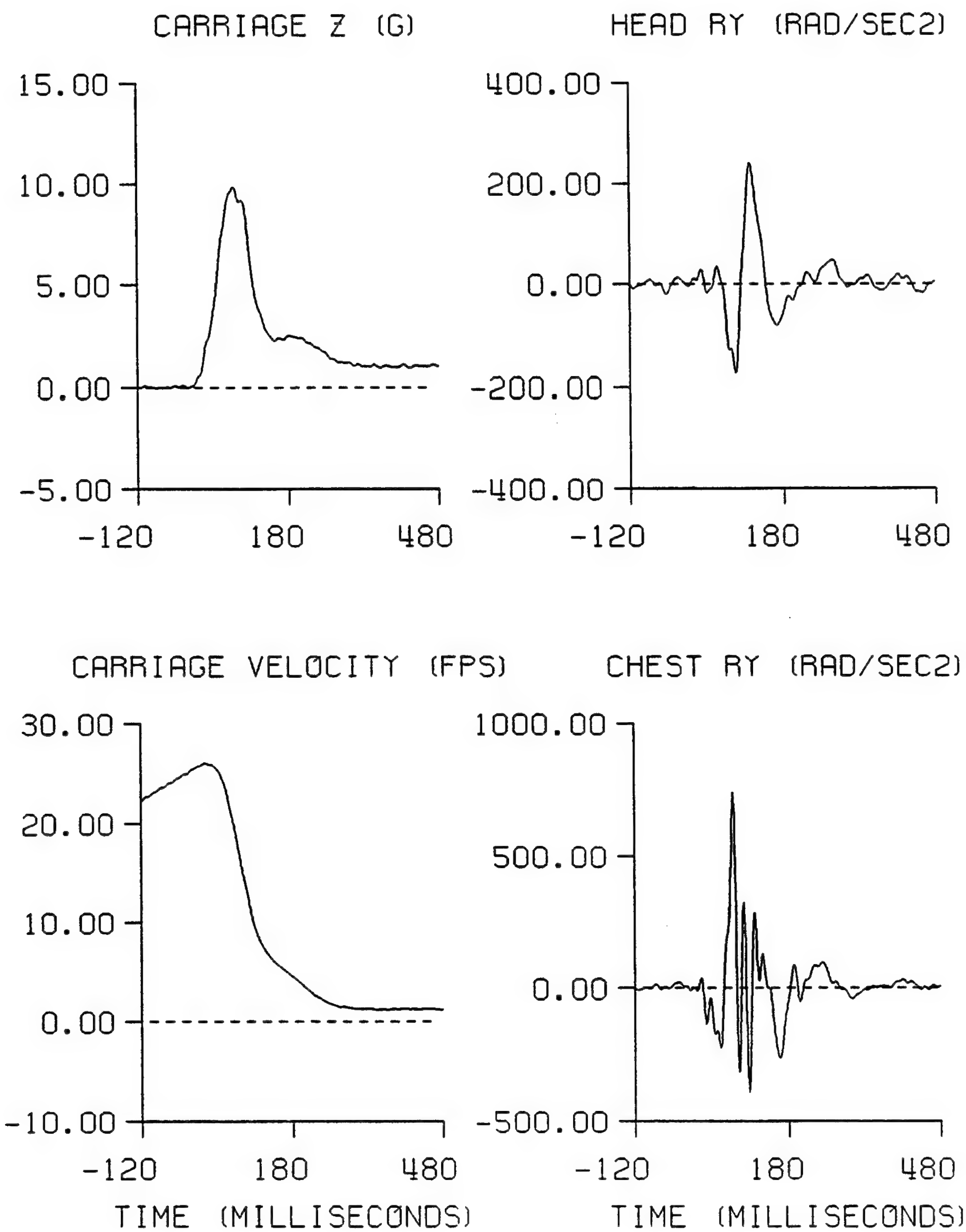
Page 1 of 2

FIP STUDY TEST: 3768 TEST DATE: 17-SEP-1996 SUBJ: B-17 WT: 133.0
NOM G: 10.0 CELL: I

DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
SHOULDER STRAP FORCES (LB)					
X AXIS	-47.76	-15.32	-87.73	187.	99.
Y AXIS	-6.07	-3.34	-12.25	33.	84.
Z AXIS	3.54	69.12	2.28	90.	427.
RESULTANT	48.27	110.07	16.71	96.	186.
LAP FORCES (LB)					
LEFT X AXIS	-66.06	-14.40	-63.90	227.	9.
LEFT Y AXIS	25.56	25.44	4.44	0.	222.
LEFT Z AXIS	-83.98	-14.42	-80.16	55.	0.
LEFT RESULTANT	109.87	105.09	22.90	0.	224.
RIGHT X AXIS	-69.59	-17.11	-67.08	393.	0.
RIGHT Y AXIS	-19.22	-2.07	-19.03	68.	5.
RIGHT Z AXIS	-88.14	-16.90	-84.16	54.	0.
RIGHT RESULTANT	113.94	109.23	26.11	0.	398.
SEAT FORCES (LB)					
LEFT X AXIS	-0.88	7.55	-2.59	18.	8.
RIGHT X AXIS	3.89	19.54	-91.99	18.	82.
X AXIS SUM	3.01	27.08	-93.32	18.	82.
Y AXIS	-6.73	33.12	-16.56	62.	119.
LEFT Z AXIS	10.17	260.10	6.63	90.	5.
RIGHT Z AXIS	47.66	423.47	30.67	93.	449.
CENTER Z AXIS	137.50	1285.33	122.97	75.	331.
Z AXIS SUM	195.34	1915.50	178.60	77.	331.
RESULTANT	195.49	1917.68	179.35	77.	331.
Z SUM MINUS TARE	218.13	1713.67	176.46	79.	334.
RESULTANT MINUS TARE	218.27	1716.20	177.22	79.	334.

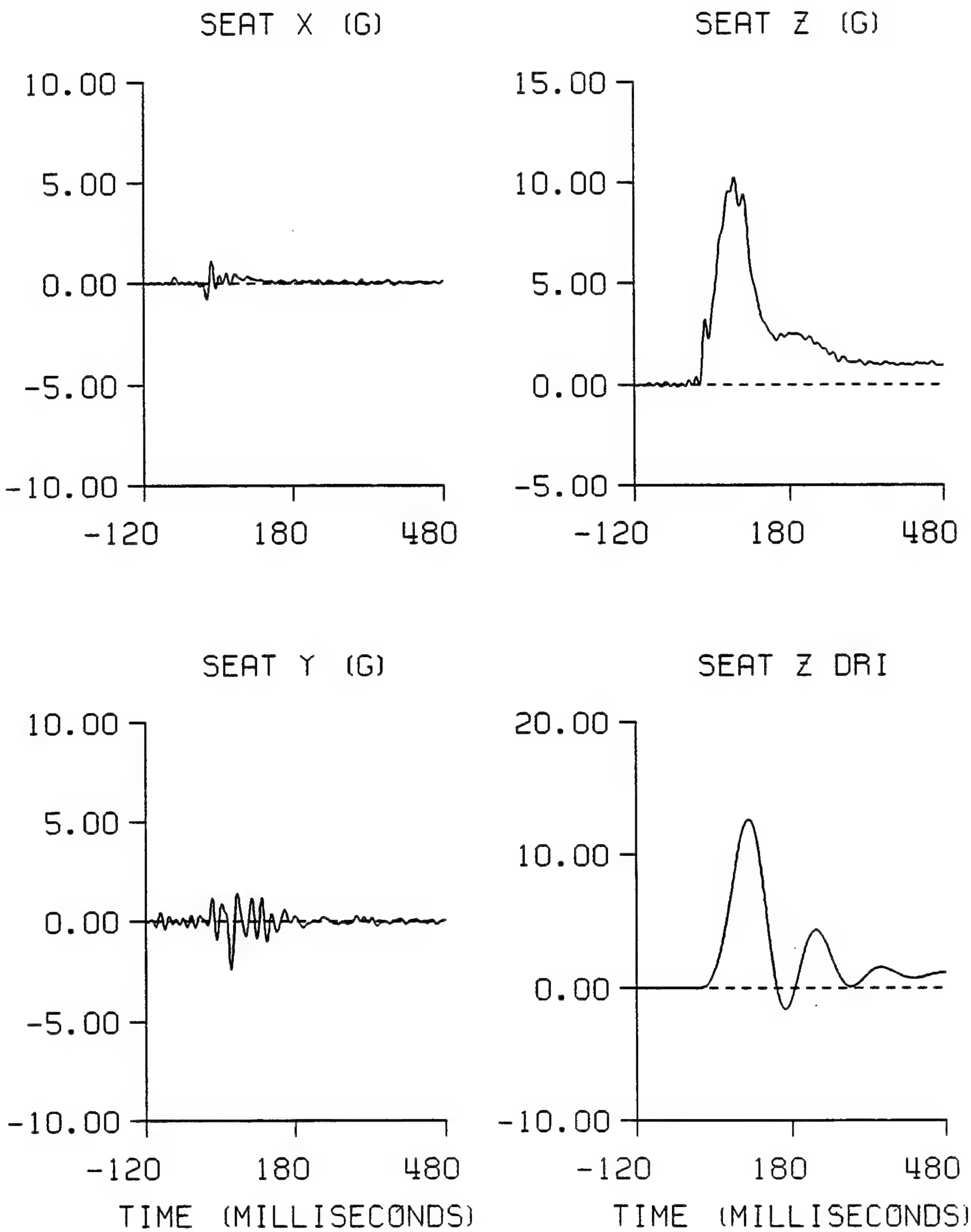
Page 2 of 2

FIP STUDY TEST: 3768 SUBJ: B-17 CELL: I

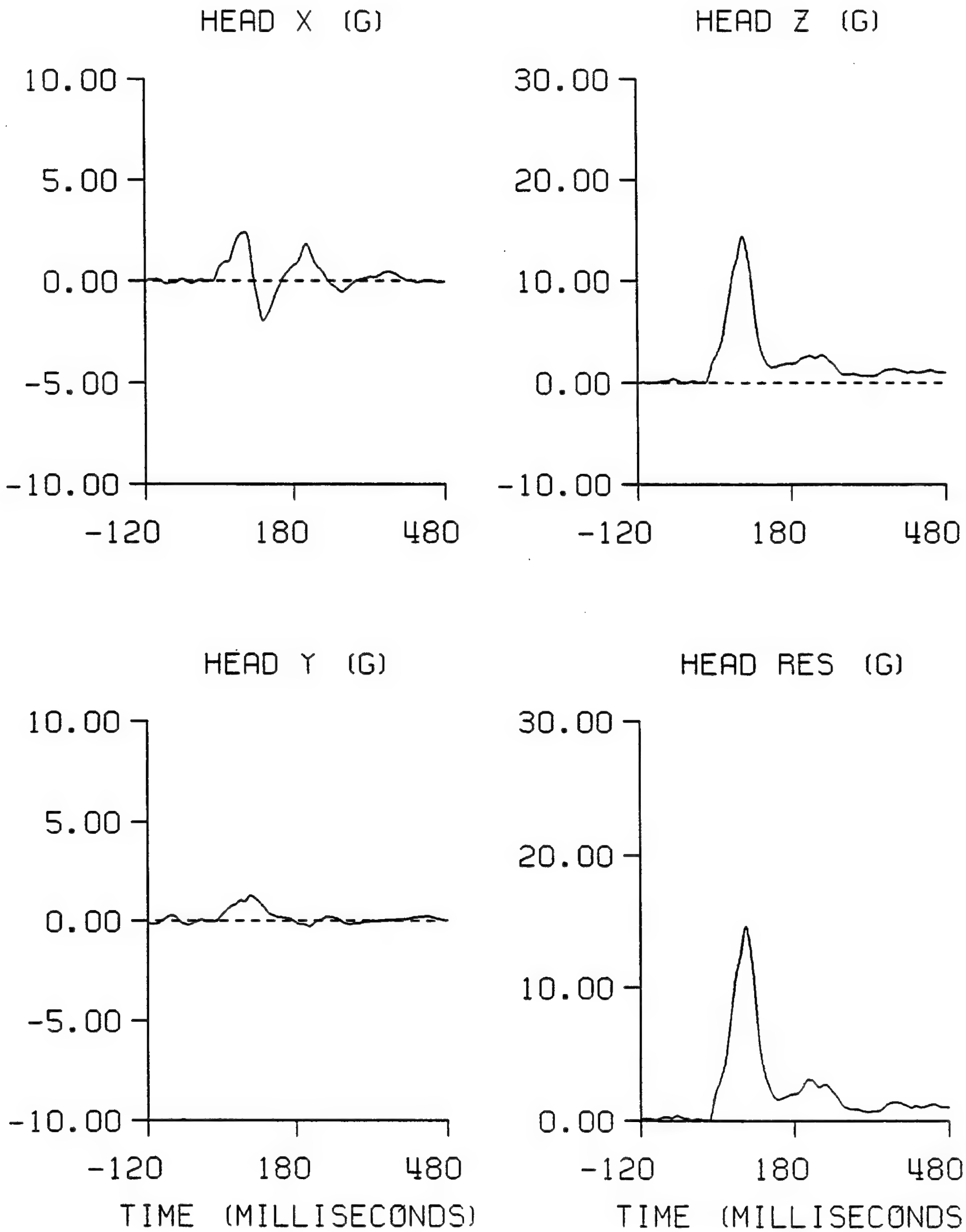


B-31

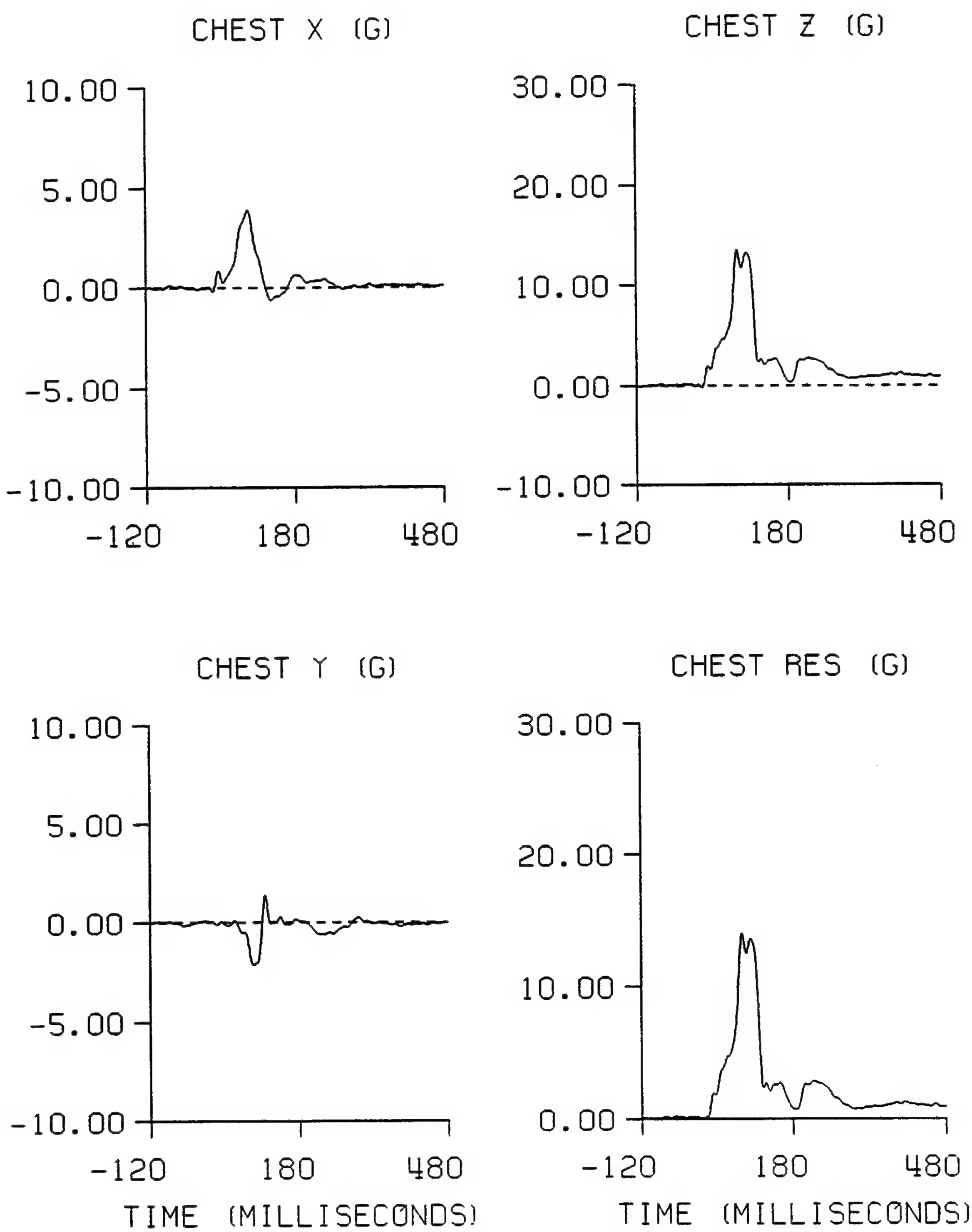
FIP STUDY TEST: 3768 SUBJ: B-17 CELL: I



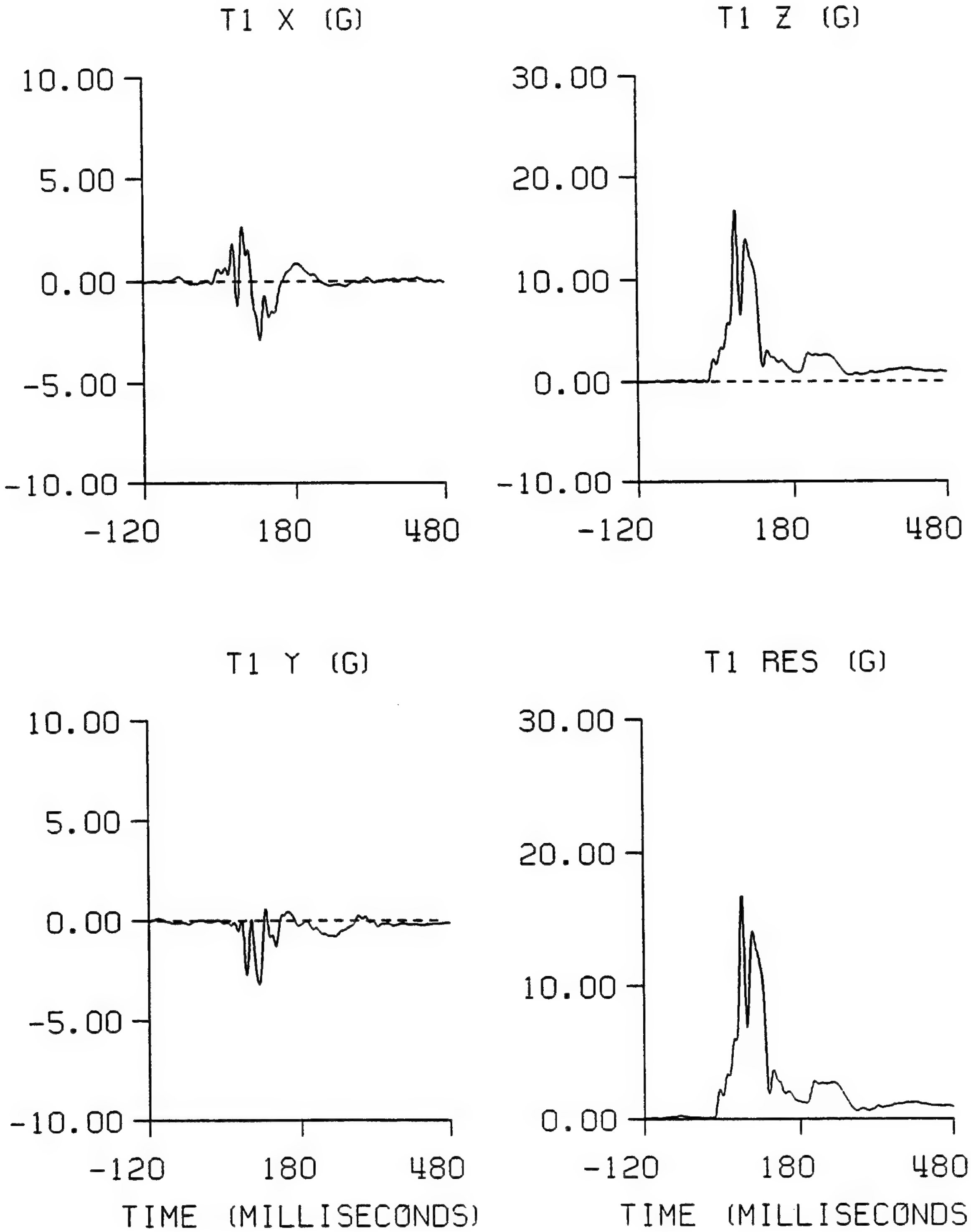
FIP STUDY TEST: 3768 SUBJ: B-17 CELL: I



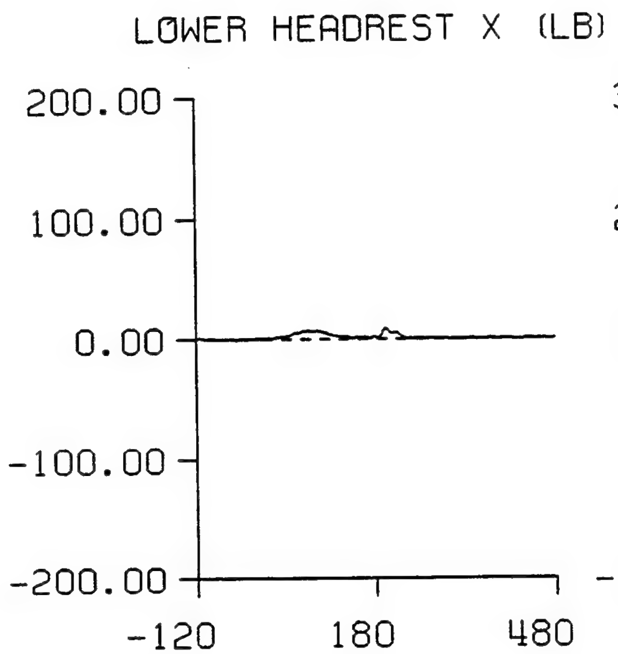
FIP STUDY TEST: 3768 SUBJ: B-17 CELL: I

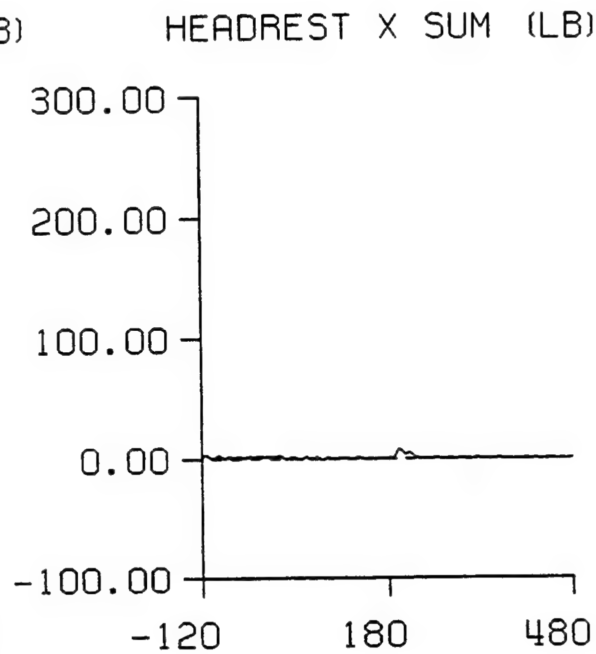


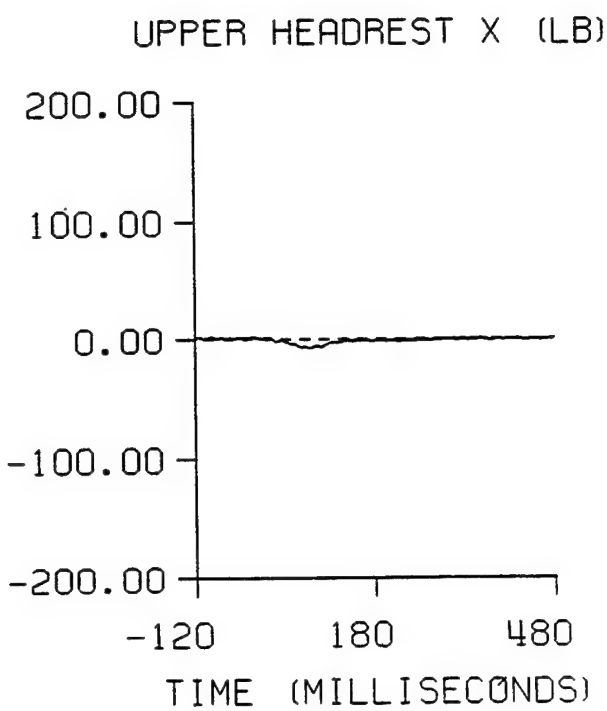
FIP STUDY TEST: 3768 SUBJ: B-17 CELL: I



FIP STUDY TEST: 3768 SUBJ: B-17 CELL: I

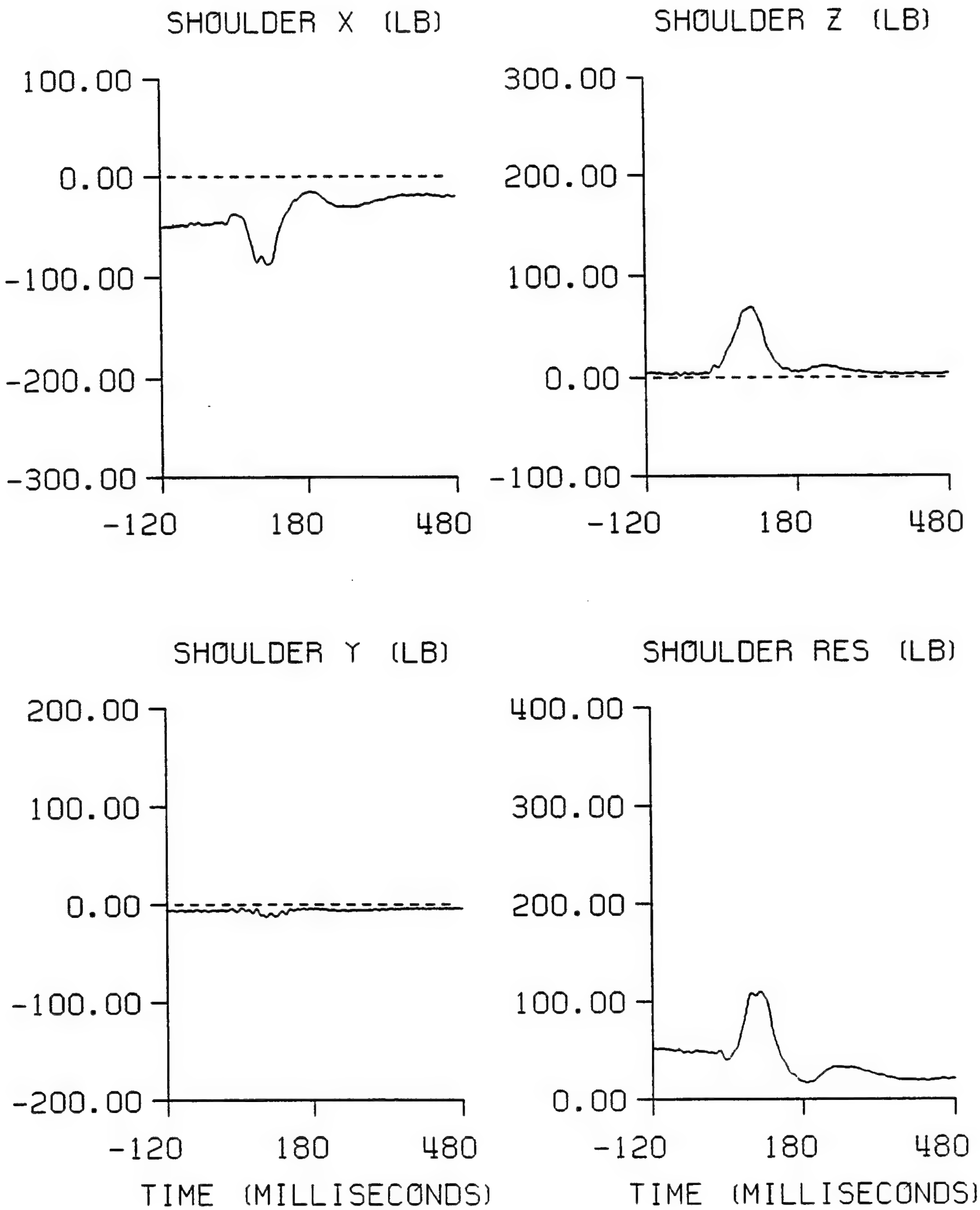






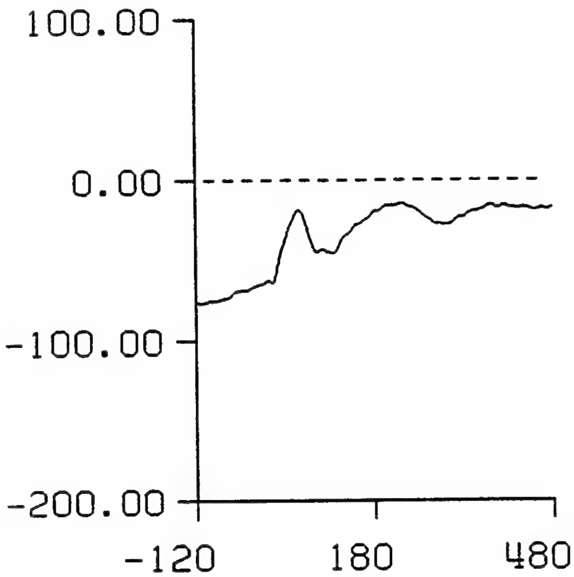
B-36

FIP STUDY TEST: 3768 SUBJ: B-17 CELL: I

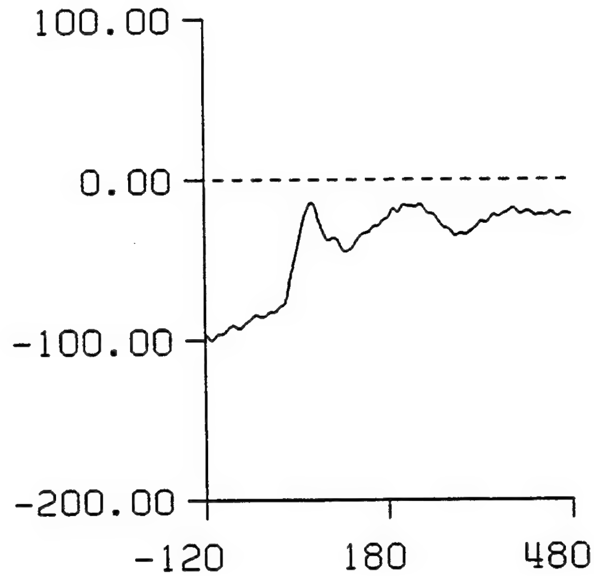


FIP STUDY TEST: 3768 SUBJ: B-17 CELL: I

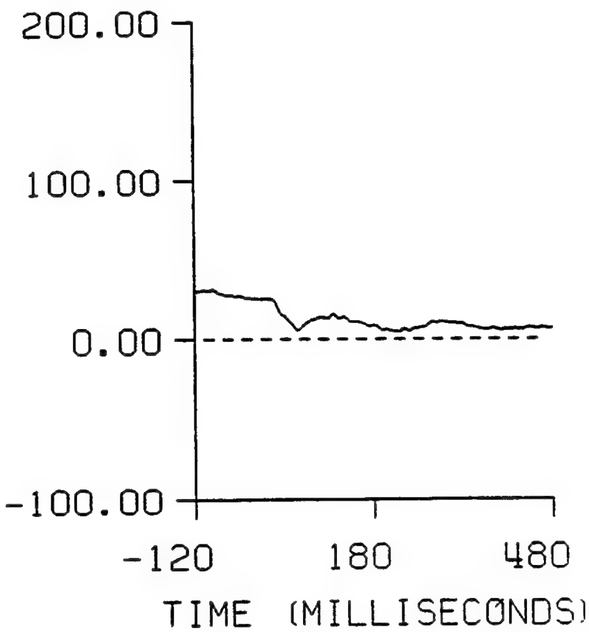
LEFT LAP X (LB)



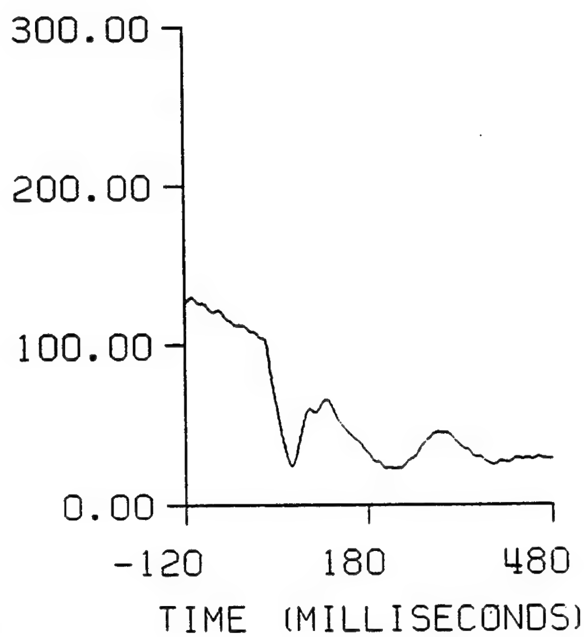
LEFT LAP Z (LB)



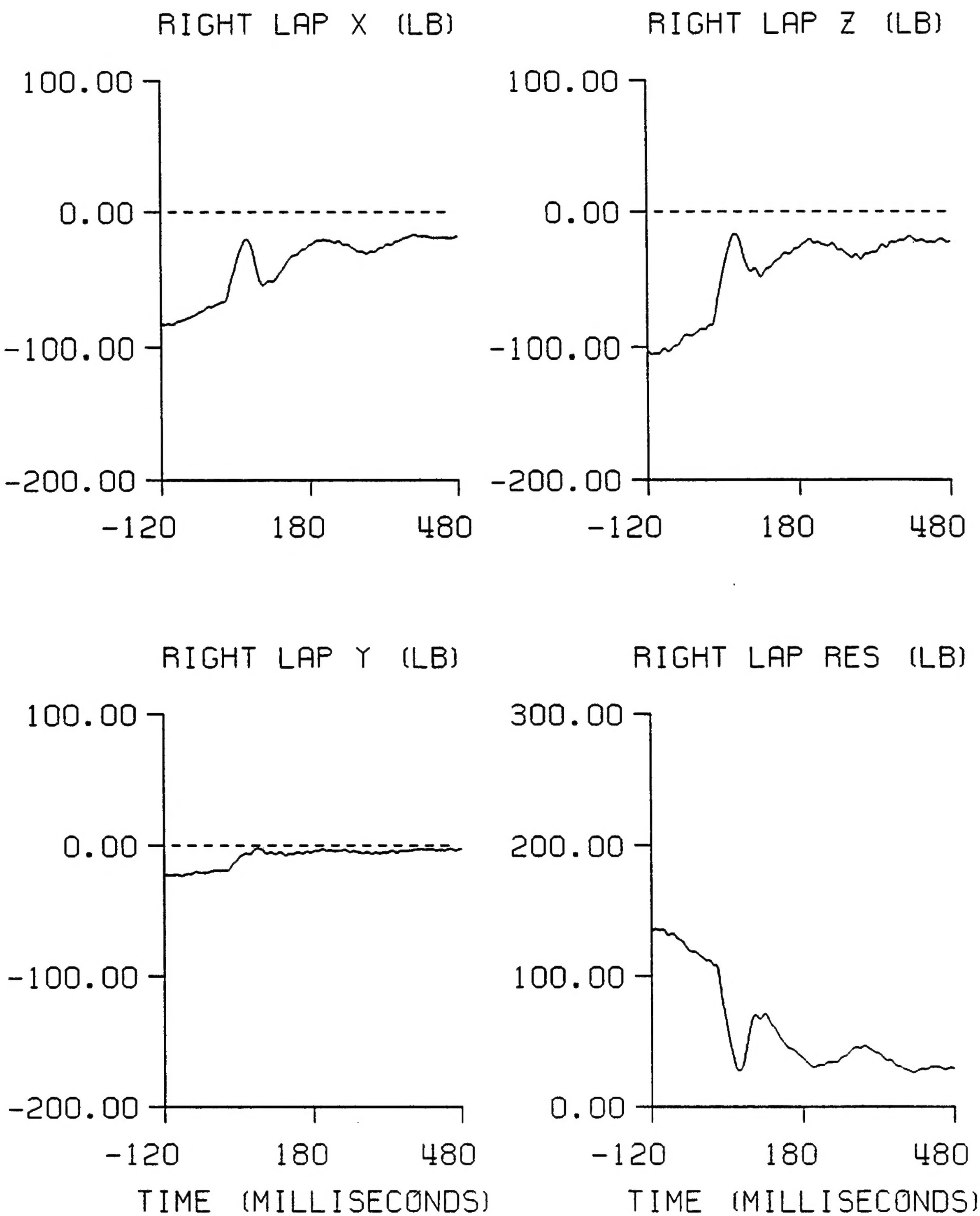
LEFT LAP Y (LB)



LEFT LAP RES (LB)



FIP STUDY TEST: 3768 SUBJ: B-17 CELL: I



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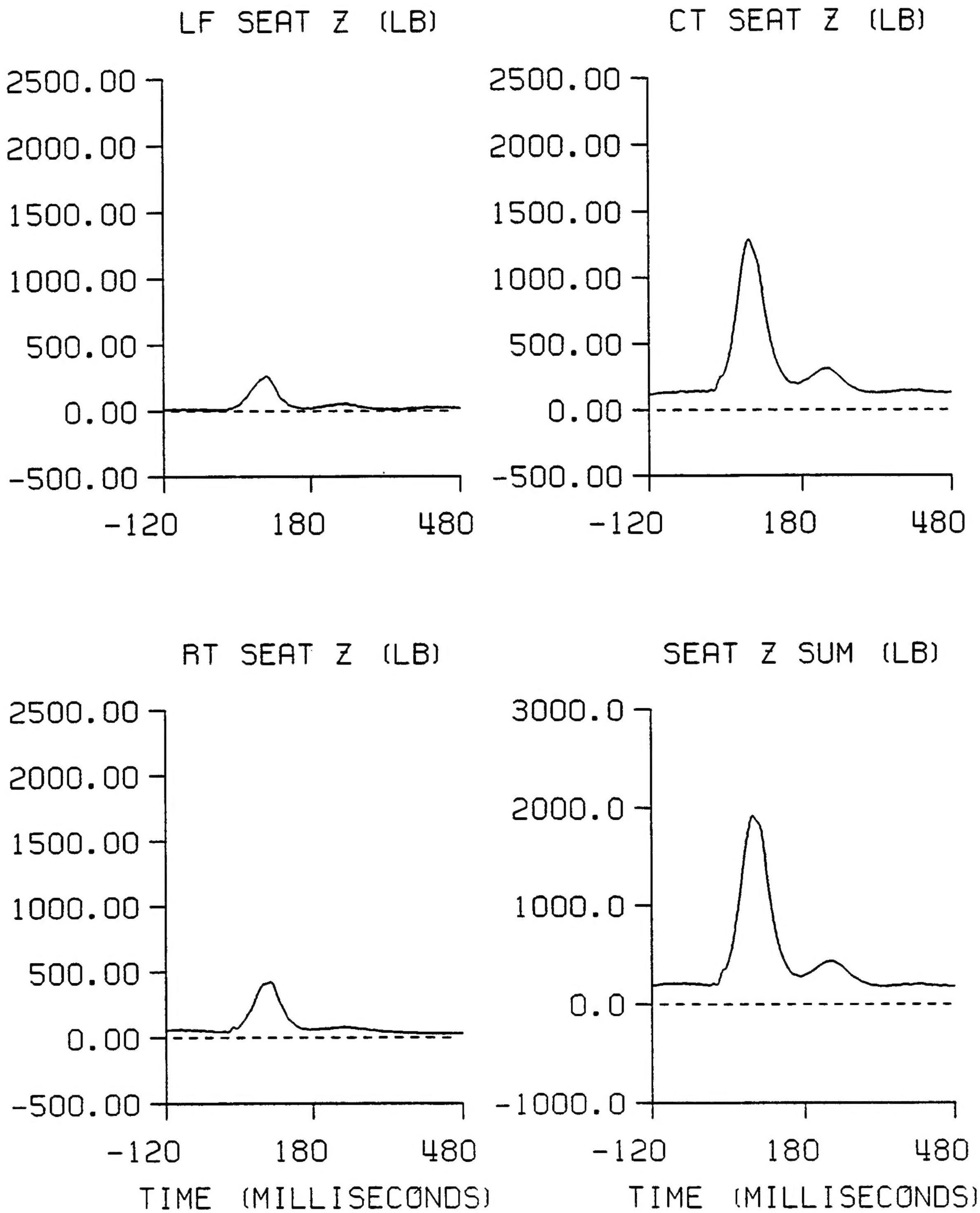
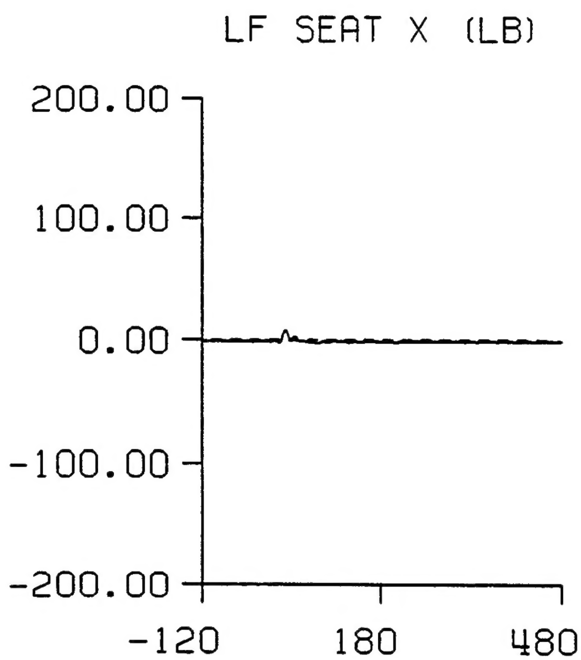
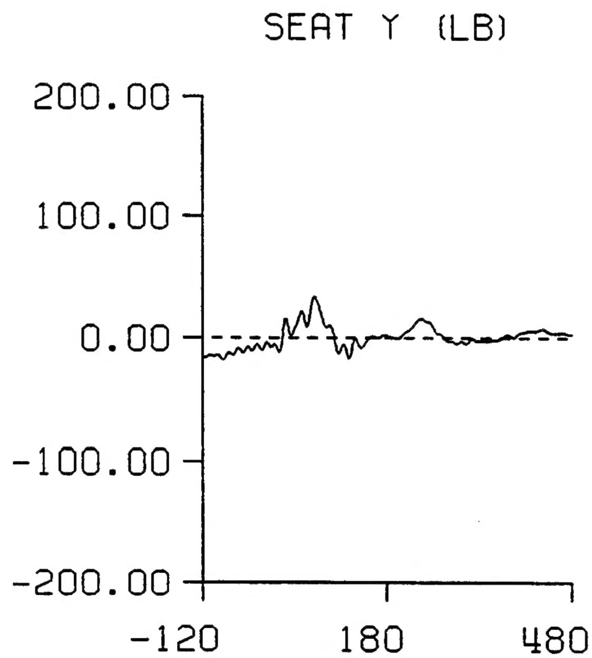
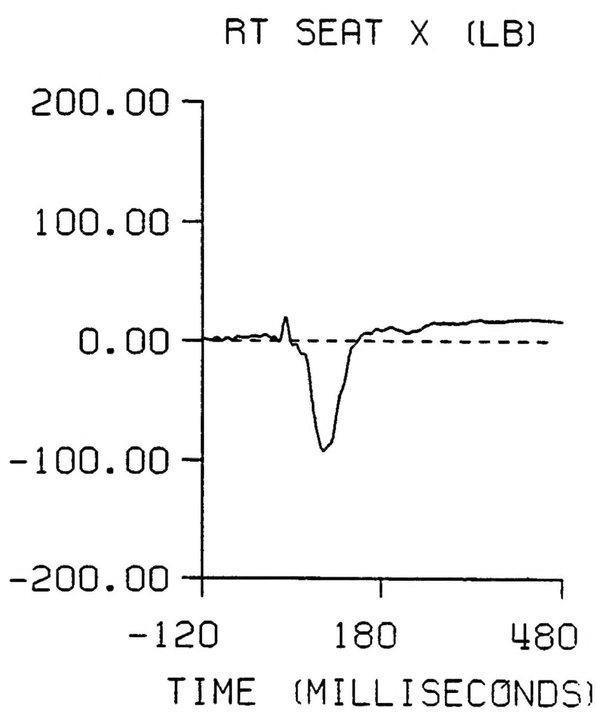
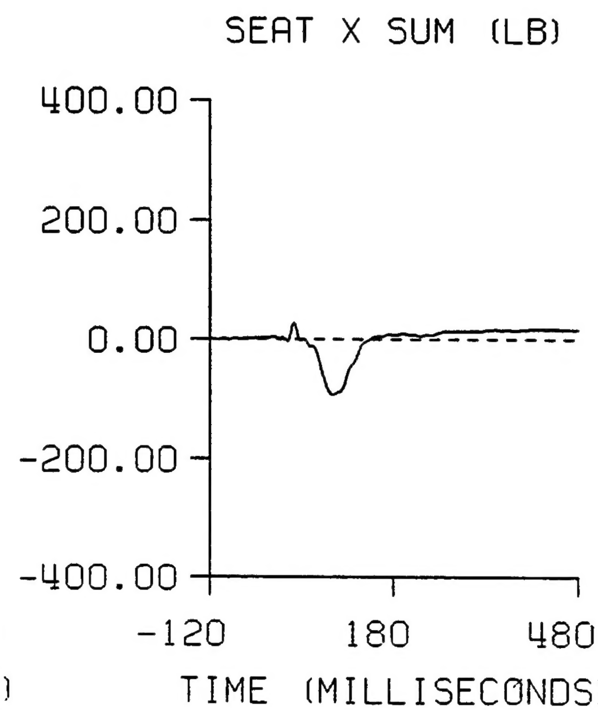


FIP STUDY TEST: 3768 SUBJ: B-17 CELL: I









FIP STUDY TEST: 3768 SUBJ: B-17 CELL: I